INDIVIDUAL DIFFERENCES IN AFFECT AND VAGAL TONE IN RESPONSE TO MODERATE- AND HIGH-INTENSITY INTERVAL EXERCISE: A PRELIMINARY MODEL

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Kinesiology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2019

Urbana, Illinois

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ABSTRACT

Background. Evidence suggests regular exercise, amongst other healthy lifestyle choices, promotes enhanced quality of life and longevity. However, the majority of adults (>85%) do not meet the requirements suggested by the U.S. Physical Activity Guidelines, thus missing out on potential benefits. Some researchers have proposed the lack of continued exercise behavior is a result of negative affective responses associated with exercising, and suggest individuals must feel good (e.g., experience pleasure) during and following (e.g., enjoyment) exercise in order to increase the likelihood of future engagement. Promising evidence to support the application of the exercise-affect-adherence relationship has emerged. However, a conundrum exists: high-intensity training programs have gained, and are maintaining, popularity, even though these often result in negative feeling states, which should decrease likelihood of adherence to such regimens. It is possible some individuals are more suited for high-intensity exercise; that is, they are predisposed to experience more pleasure or less displeasure during high-intensity exercise leading to a desire for continued future engagement. **Purpose**. To examine affective and vagal tone reactivity to and recovery from an acute bout of moderate-intensity (MIIE) and high-intensity interval exercise (HIIE), and to consider how individual differences (e.g., personality, biological dispositions) influence these responses. **Methods.** Participants (N= 25, 13 females, 23.3±4.0 yrs, BMI= 25.7±4.1 kg·m^{-2}, HR$_{rest}$= 68.12±11.66 b·min^{-1}, VO$_{2peak}$= 41.57±9.42 ml·kg^{-1}·min^{-1}) completed 4 sessions at the same time of day on different days, with at least 24-hours between each session. Refraining from exercise (24-hours prior), caffeine (8-hours prior), and alcohol (12-hours prior), participants completed a baseline session to record resting affect and cardiac vagal tone. Personality, regulation-style, and emotional complaints (i.e., Anxiety, Depression, and Stress) were also assessed via questionnaire. Participants completed a graded exercise test on a stationary bike (cycle ramp protocol 25 W·min^{-1}) to volitional exhaustion during the second session, where peak oxygen consumption, peak heart rate, and oxygen consumption at ventilatory threshold (VT) were determined. Based on individual workload at VT, a relative high- (5% below relative load at VT) and moderate-intensity (25% below relative load at VT) load was determined for sessions 3 and 4. Participants then completed a high- (HIIE) and moderate-intensity interval exercise (MIIE) session (5 intervals of 3-min of exercise to 1-min of rest) where affect and vagal tone were recorded prior to, during, and up to 30-minutes post exercise. The HIIE and MIIE sessions were randomized and counterbalanced in order to control for pre-exercise states. In addition, participants were blinded to the condition intensities. **Results**. Participants reported more negative feeling states and experienced greater vagal tone withdrawal during the HIIE session compared to the MIIE session, but these states recovered similarly as early as 5-minutes post-exercise. In addition, individual characteristics (i.e., fitness), traits (e.g., Extraversion, Conscientiousness, Neuroticism), emotional complaints (i.e., Depression, Anxiety, and Stress), and biological dispositions (e.g., tonic vagal tone) provided predictive variance on affective reactivity (i.e., valence) during the HIIE session. This suggests some individuals are predisposed to respond more positively to high-intensity exercise. **Conclusions**. These findings indicate that some individuals may thrive (i.e., initiate and adhere) in a high-intensity exercise program, while others are more likely to experience displeasure and potentially drop-out. In order to optimize exercise programming, or simply encourage exercise behavior, it is important to consider each individual's unique set of characteristics at exercise initiation.

ACKNOWLEDGEMENTS

To my friends, mom, and brother for the love, support, and the always seemingly needed laugh, thank you. You all made the uncounted hours devoted to this project bearable.

To my unparalleled mentors Dr. P and Dr. Feito, I would be a spinning wheel that has gained no traction without you. Thank you Dr. P for the numerous ‘brain-storms’ and confidence boosts throughout these first couple of years. Thank you Dr. Feito for the timely phone calls and check-ins to listen and keep me from cliff-jumping, your words of encouragement, discipline, and humor always provided the spur needed to keep my “head down and keep working”.

To my dad, your unwillingness to give up, your proclivity to give more than take, and your gift to love unconditionally has shaped me into who I am, and who I strive to be. I dedicate this project, the first-step of a career you always dreamed for me, with all of my love to you.

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CHAPTER 1: INTRODUCTION

The preventive and therapeutic benefits of exercise have been well-studied. Extensive evidence suggests regular exercise behavior (e.g.,, 150-min of moderate- or 75-min of high-intensity exercise per week, coupled with at least 2-days of resistance training; U.S. Department of Health & Human Services, 2018) reduces the risk for developing sedentary-related diseases (e.g., coronary heart disease, type II diabetes-mellitus, osteoarthritis), some cancers (e.g., breast, prostate), and neurological diseases (e.g., Alzheimer's, dementia, stroke; Arem et al., 2015; McKinney et al., 2016; PAGAC, 2018). Additionally, regular exercise has been shown to alleviate symptoms of several psychological disorders, including general anxiety, depression, and chronic and traumatic stress (Asmundson et al., 2013; Checkroud et al., 2018). However, despite the educational efforts to promote exercise for physical health, the large majority of adults around the world do not engage in regular exercise, with studies suggesting less than 12% of adults are meeting physical activity guidelines (Kapteyn et al., 2018; Tucker, Welk, & Beyler, 2011). Understanding why people do (or do not) exercise is paramount for public health promotion.

A potential, promising avenue for exercise behavior is exercise hedonics (i.e., un/pleasant feelings; Ekkekakis, 2009a, b). This is the belief that individuals will choose to engage, and continue to engage, in a behavior that is perceived as pleasant while avoiding a behavior perceived as unpleasant (Rhodes & Kates, 2015; Williams et al., 2008; Young, 1952). The conceptual framework of hedonic behavior is not novel; it has been recognized in the psychology literature for the better half of the past century. With this conceptual foundation, Brand and Ekkekakis (2018) developed a theoretical model in which exercise-pleasure reactivity is accentuated, in that an individual will have an affective reaction (which was associated with prior exercise feeling states) to an exercise stimulus. In addition, they propose the importance of reflection, or cognitive appraisal (e.g., weighing risks/benefits), and self-control for future and/or continued exercise behavior. As such, individuals who have a positive affective reaction (e.g., pleasure, enjoyment) coupled with positive cognitive appraisal (e.g., 'exercising is good for my health') are more likely to engage in exercise behavior, while those who have a negative affective reaction (e.g., displeasure) and a negative cognitive appraisal (e.g., 'the gym is too expensive') are unlikely to continue exercise.

Considering the potential importance of exercise hedonics (i.e., experienced pleasure or displeasure) for future exercise behavior, investigators have begun exploring how exercise intensity (among other exercise variations such as volume, duration, and/or mode) may influence these feeling states. It is generally believed that high-intensity, continuous exercise elicits a more negative (or less positive) affective response when compared to low and moderate-intensity continuous exercise (Ekkekakis & Petruzzello, 1999; Ekkekakis, Parfitt, & Petruzzello, 2011). Further, although less understood, high-intensity interval exercise (i.e., exercise comprised of pre-determined rest or low-intensity recovery and high-intensity work intervals) also follows this trend, with the majority of individuals reporting less positive affective states compared to moderate-intensity interval exercise (Greene, Greenlee, & Petruzzello, 2018; Jung, Bourne, & Little, 2014; Stork, Banfield, Gibala, & Martin-Ginis, 2017). Despite the general inclination that high-intensity exercise will produce less pleasurable feeling states during exercise, high-intensity interval training has been listed as a top fitness trend for the past 5 years (Thompson, 2018). The question then presents itself: are there individual differences that result in someone responding more positively (or less negatively) to high-intensity exercise, and is that the reason for the propensity to continue in high-intensity exercise programming?

It is likely that individual differences (e.g., personality traits, biological dispositions) act as antecedents or mediators to the high-intensity hedonic response. Thus, the overarching aim of the present study was to examine the extent of affective (feeling state) and cardio-neural (vagal tone) state changes during and following high-intensity interval exercise and explore how (and to what extent) personality traits (e.g., exercise intensity preference and tolerance, extraversion, neuroticism, & conscientiousness) and biological dispositions (i.e., cortical frontal asymmetry, vagal tone) influence affective reactivity and recovery.

CHAPTER 2: REVIEW OF LITERATURE

2.1 Affective Responses

Affective responses broadly refers to individuals' psychological feeling states, which have been conceptualized into three affective constructs: core affect, emotions, and mood states. It is important to understand these affective constructs have distinct conceptual differences (Russell & Barrett, 1999), even though they are often misinterpreted and used interchangeably (Ekkekakis, 2013). Core affect is the most general "consciously accessible feeling", which is most often reflected as pleasure or displeasure (Russell & Barrett, 1999, pg. 806). Emotional states (i.e., emotions) typically occur immediately following a specific event, are intense, and dissipate in a short period of time; conversely, mood states may or may not be associated with an event, are less intense, and are typically longer lasting (i.e., days, months; Ekkekakis, 2013).

Within the exercise literature, core affect is commonly expressed using a 2-dimensional space, where valence (i.e., general sense of pleasure or displeasure) is coupled with sensation and perception of physiological activation (e.g., the feeling of a rapid heartbeat, muscle tension). Shifts in this 2-dimensional core affect can be mapped using the Circumplex Model (see Figure 2.1; Russell & Barrett, 1999). Fluctuations in core affect reflect the subtle changes in how one is feeling and result from shifts in feeling generally pleasant to unpleasant, activated to deactivated, or (more likely) some combination of both. Further, Thayer (1986) suggested there are four quadrants comprising the 2-dimensional activation–valence continuum: high activation-pleasant (i.e., energy), high activation-unpleasant (i.e., tension), low activation-unpleasant (i.e., tiredness), and low activation-pleasant (i.e., calmness). Mounting evidence has provided additional emotions that can be associated with variability on the Circumplex (see Ekkekakis, 2013, pg. 58). With the knowledge of affective concepts, it is reasonable to test both core affect and emotional state reactivity and recovery to an exercise stimulus, while examining mood states should be reserved for intervention-based (i.e., longer-term) studies focusing on clinical (e.g., depression, anxiety disorders) populations where affective states may be chronically compromised (e.g., elevated, enduring levels of fatigue). For the aims of the present study, core affect and emotional reactivity and recovery will be the primary foci.

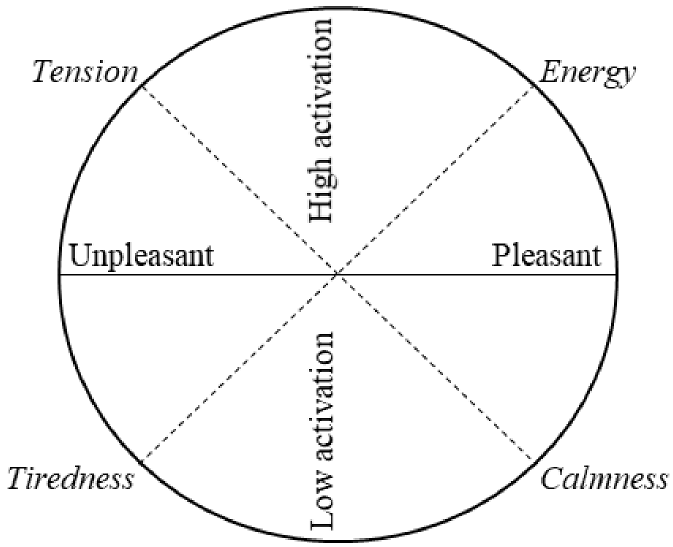

Figure 2.1. Diagram of Circumplex Model of Affect (**Note**. Illustration adapted from Ekkekakis (2013, pg. 122, Figure 7.1))

Considering the prevalence of high intensity exercise programs, a consistent theme in the exercise-affect literature has emerged. Specifically, high-intensity continuous exercise (i.e., without rest breaks) elicits a more negative (or less positive) feeling state when compared to light- and moderate-intensity continuous exercise (Acevedo, Kraemer, Haltom, & Tryniecki, 2003; Ekkekakis, Hall, & Petruzzello, 2005b, 2008; Ekkekakis, Parfitt, & Petruzzello, 2011; Ekkekakis & Petruzzello, 1999). However, these negative feelings typically dissipate (i.e., return to pre-exercise state) immediately following exercise cessation and may even produce a more positive feeling state during recovery than before high-intensity exercise engagement (Hall, Ekkekakis, & Petruzzello, 2002; Tate & Petruzzello, 1995). Regardless, general promotion of high-intensity exercise has been argued against, as the majority of individuals, especially those who are un-fit and overweight (Ekkekakis & Lind, 2016), experience negative feeling states while exercising at a high-intensity, and this negative association will likely lead to reductions (or cessation altogether) in exercise behavior (see Biddle & Batterham, 2015 for HIT promotion for public health debate).

With growing interest over the past couple of decades, this high-intensity exercise-affect relationship has been illuminated, with a clear trend having emerged. The following highlights the evidence across these decades. Tate and Petruzzello (1995) examined affective responses in 20 college-aged students to varying exercise intensities. Students were randomly assigned to a control, a moderate intensity (55% VO_{2max}), or high intensity (70% VO_{2max}) condition where affective measurements were obtained before, immediately following, and during a 30-minute recovery period. The control (non-exercise) condition did not result in any affective changes; both exercise conditions resulted in immediate increases in state anxiety, followed by a significant drop in anxiety following a recovery period in the high-intensity condition. However, feelings of energy were greater for both exercise conditions compared to control, but lasted longer following the high-intensity condition. In a study completed by Hall, Ekkekakis, and Petruzzello (2002), 30 college-aged students, with above average fitness levels (VO_{2max} of 49.6 $ml \cdot kg^{-1} \cdot min^{-1}$), completed a treadmill run to exhaustion. Affect was recorded before, during (every 1-minute), and up to 20 minutes post-exercise. To standardize relative intensity, affect and perceived exertion were compared at the beginning of exercise, at the ventilatory threshold, and at the end of exercise, as duration to completion varied widely by individual. Increases in energy and decreases in tension were reported from pre- to post-exercise. Further, valence (pleasure/displeasure) only declined into an “unpleasant” state at the final point of exhaustion, but quickly rebounded to and beyond pre-exercise levels following exercise cessation. These studies, among several others, consistently suggest homogeneous pleasure at exercise intensities below the ventilatory threshold, large variability in valence at the ventilatory threshold, and homogeneous displeasure at exercise intensities above the ventilatory threshold (Acevedo, Kraemer, Haltom, & Tryniecki, 2003; Ekkekakis, 2009a, b; Ekkekakis, Hall, & Petruzzello, 2005b, 2008). Although evidence has repeatedly supported affective decline during high-intensity continuous exercise, it is important to note the degree and duration of affective decline is thought to be dependent on physical fitness levels; those with greater fitness report a less pronounced drop in positive feeling states (Ekkekakis & Petruzzello, 1999). Additionally, individual differences (e.g., high-intensity preference and tolerance) produce variations in fitness performance (Hall, Petruzzello, Ekkekakis, Miller, & Bixby, 2014) and self-selected exercise intensity (Ekkekakis, Lind, & Joens-Matre, 2006). Some evidence suggests personality traits mediate affective reactivity during high-intensity exercise, where individuals with greater trait tendencies of high-intensity preference and tolerance report more pleasant feelings states during high-intensity exercise (Box & Petruzzello, 2019).

Less agreed upon is affective reactivity and recovery to interval exercise, which is exercise with a pre-determined work-to-rest ratio. In a more recent examination of differing exercise intensities, Greene, Greenlee, and Petruzzello (2018) recorded affective change during control (reading), moderate- (walking), and high-intensity (high-intensity interval, body weight circuit) conditions. College-aged, active individuals (*N*=366) completed all experimental conditions with affect recorded prior to-, during (every 3 minutes), immediately post-, and at 20 minutes post-conditions. Walking resulted in greater improvements in affective valence during the condition compared to the high-intensity circuit; however, the high-intensity circuit elicited a more positive feeling state at 20-minutes-post when compared to pre-exercise. Jung, Bourne, and Little (2014) compared inactive individuals' affective responses prior-to, during, and following a 20-min high-intensity interval (1-min of maximal effort alternating with 1-min of light exercise), a 20-min high-intensity continuous, and a 40-min moderate-intensity continuous bout. Their findings showed the high-intensity continuous exercise resulted in more negative affective states compared to the moderate-intensity continuous exercise, and that the high-intensity interval bout was more pleasurable following completion when compared to the high-intensity continuous bout. In a review completed by Stork et al. (2017), comparisons of affective responses between interval- and continuous-exercise resulted in mixed findings. While some studies reported more negative states during high-intensity intervals compared to high- and moderate-intensity continuous exercise, others did not observe any differences.

A potential problem with these comparison studies were the methodologies applied, as more than one exercise variable was manipulated. It is reasonable to assume that greater intensity will result in a greater likelihood of experiencing negative affect; however, as intensity of exercise interacts with exercise duration, duration must be properly considered. That is, experiencing a controlled load for longer durations elicits greater relative intensity when compared to shorter durations (e.g., drift in various physiological parameters with increasing duration). Caution must be utilized in interpreting comparisons of interval and continuous exercise if: 1) relative intensity (e.g., %HR_{max}, %VO_{2peak}) of exercise is not appropriately accounted for or reported; or 2) duration (not considering rest-intervals) or mode is not standardized between conditions. Thus, it remains uncertain as to which type of exercise, interval or continuous, produces more positive affective responses during high-intensity exercise, and further breakdown (i.e., exploration of affective rebounds during the exercise) of affective reactivity and recovery to differing exercise-intensity intervals is needed.

In summary, high-intensity exercise (e.g., ≥ VT) may result in a less positive feeling state during exercise, but individuals will likely report greater, more positive feeling states during recovery when compared to moderate-intensity exercise. Additionally, it is likely that individual differences influence the degree to which affective reactivity and recovery occur.

2.2 Brain Activation Responses

In the exercise domain, many researchers seek to determine how and to what extent an exercise stimulus alters the body, commonly the cardiovascular and musculoskeletal systems, and how exercise alters the mind (e.g., anxiety, depression, and stress symptom reductions). Mounting evidence suggests exercise is a viable preventative measure to reduce risk for physical and mental diseases (PAGAC, 2018). In spite of the extensive evidence, many individuals choose not to engage in exercise, which may be explained by the displeasure experienced during exercise (e.g., exercise hedonics). As such, some researchers have focused their attention on the links between exercise-affect (i.e., how one feels prior to, during, and following exercise) and exercise behavior. Of present interest is how psychophysiological traits (e.g., brain activity) coupled with behavior styles, influence how one feels and how the body responds to exercise-intensity stimuli.

The Valence-Motivation Model, proposed by Davidson (1992), postulates that frontal cortical activity (i.e., asymmetry of activation in left and right frontal cortex) reflects a biological disposition to respond more positively (greater relative left frontal hemispheric activation) or more negatively (greater relative right frontal hemispheric activation) given a significant stressor/stimuli. This is further dependent on an individual's neural threshold. Davidson and colleagues (1990, 1992) also suggested that such anterior brain asymmetries reflect the control of approach and withdrawal-related motivation behaviors, and these behaviors are adaptive and generate positive and negative affective states (i.e., how one feels). More simply, a typical pattern (i.e., biological disposition) of frontal cortical asymmetry may predict affective-motivational responses, while cortical activation may also occur following a stimulus response (i.e., state-dependent response), which may be associated with affective reactivity.

These variations in dispositional brain activity asymmetry have potential for predicting how an individual may feel during exercise, specifically high-intensity exercise that exceeds an individual's neural threshold (i.e., stressor). As this biological marker may forecast how someone responds during and following a stressful (e.g., high-intensity) exercise bout, it is an avenue to explore the mind-body connection.

Previous research has indicated that individuals with greater relative left-frontal hemispheric activation report greater reductions in state anxiety, increases in positive affect, and increases in energy compared to those with greater relative right-frontal activation (Hall, Ekkekakis, & Petruzzello, 2007; Petruzzello, Hall, & Ekkekakis, 2001; Petruzzello & Landers, 1994). However, the relationship between dispositional frontal cortical asymmetry and affective responses was only demonstrated during higher-intensity (e.g., 70% VO_{2max}) exercise conditions (Hall, Ekkekakis, & Petruzzello, 1999; Petruzzello & Landers, 1994; Petruzzello & Tate, 1997), which likely induced a stressed state. Petruzzello and Landers (1994) examined frontal brain activation and affective responses in 20 fit (average VO_{2max} of 54.96 $ml \cdot kg^{-1} \cdot min^{-1}$) college-aged males during a high-intensity (75% VO_{2max}), 30-minute treadmill exercise bout. Anxiety reductions were reported post-exercise, where a relationship was found between greater relative left frontal activation prior to exercise and greater anxiety reduction following exercise. In a study completed by Petruzzello and Tate (1997), 20 college-aged participants who were considered high-fit (95th percentile VO_{2max}) completed a graded exercise test to exhaustion, a control (no exercise), a moderate-intensity (55% VO_{2max}) and a high-intensity (70% VO_{2max}) exercise condition. Resting electroencephalography (EEG) and affect were recorded prior to knowledge of session condition, immediately-post (within 60-seconds), and during a recovery period up to 30-minutes post-exercise. Frontal asymmetry did not predict affect or anxiety states during any condition. However, resting frontal cortical asymmetry did contribute to unique variances in affect and anxiety following the high-intensity condition; those with greater relative left-hemispheric activation reported greater reductions in post-exercise state anxiety and more pleasant feelings. Petruzzello, Hall, and Ekkekakis (2001) also examined the differences in frontal cortical activation and affective change during a high-intensity (75% VO_{2max}) treadmill run by comparing low-fit and high-fit individuals before, immediately post-, and up to 30 minutes post-exercise. They report that frontal asymmetry predicted affective change, specifically energy, during recovery at 20-minutes post exercise, and energy increased more so for the high-fit individuals. Further, those with relatively greater left-hemispheric activation had significantly larger increases in energy, and energy remained elevated for a longer period of time compared to individuals with relatively greater right-hemispheric activation. As it seems dispositional anterior asymmetry most influences affective change at higher intensities, Hall, Ekkekakis, & Petruzzello (2007) then examined frontal cortical activation and affect in 30 fit, college-aged students during a graded exercise test on a treadmill. Their results indicated that greater resting anterior left-hemisphere activation accounted for variance in calmness and tiredness following the maximal exercise.

As Davidson (1992) mentioned in his Approach-Avoidance Framework, frontal asymmetry can only predict affect following presentation of a "sufficient" stimulus, thus it is reasonable to assume lower-intensity (e.g., 55% VO_{2max}) exercise does not elicit a sufficient stimulus, at least in younger and relatively fit individuals. As dispositional frontal asymmetry seems to only be predictive of affect for exercise intensities that elicit a significant stress response, it is of interest whether dispositional frontal asymmetry differs among individuals who regularly exercise at high-intensity, and whether these differences predict affective reactivity and recovery during high-intensity interval exercise.

2.3 Cardiac Vagal Tone Responses

Heart Rate Variability (HRV) is an index of autonomic nervous system (ANS) innervation. The ANS is comprised of the parasympathetic nervous system (indicative of a more relaxed state), which continuously interacts with the sympathetic nervous system (indicative of a more stressed state) to determine autonomic balance. In recording an individual's HRV, one is presumably capturing the state of parasympathetic influence (or lack of), that is cardiac vagal tone, directed from the vagal nerve (Bernston & Cacioppo, 2003). Not surprisingly, these nerve impulses are constantly firing, resulting in important balances and counter-balances of the ANS.

HRV has become a viable psychophysiological variable to explore affective disorders, stress reactivity and recovery, and more general explorations into quality of life (Bertsch, Hagemann, Naumann, Schachinger, & Schulz, 2012; Laborde, Mosley, & Thayer, 2017; Verkuil, Brosschot, Tollenaar, Lane, & Thayer, 2016). In addition, Thayer, Åhs, Fredrikson, Sollers, and Wager (2012) proposed HRV as a dispositional psychobiological marker that remains consistent across time and situations (i.e., trait index) and influences an individual's situational response or adaptability to a given stressor. When examining HRV as a trait index, it is generally agreed upon that greater tonic (i.e., resting) variability in heart beats (i.e., HRV) is associated with less stress and emotional disorders, better quality of life, and a likelihood to respond more optimally to a stressor, which could be emotional, social, or physical. However, a normal shift towards vagal (parasympathetic) withdrawal is expected when a stressor is presented, with the degree and timing of phasic (i.e., reactive) vagal withdrawal being related to task-performance. A large body of HRV literature has shown this tonic vagal tone to be an index of psychophysiological responses. That is, it has been linked with psychosomatic symptoms associated with emotional disorders (e.g., anxiety, depression, and stress; Bernston & Cacioppo, 2003; Chalmers, Quintana, Abbott, & Kemp, 2014; Kemp et al., 2010; Thayer et al., 2012).

The emergence of HRV in the exercise domain has been predominantly with respect to exercise and sport performance. Greater tonic variability between successive heartbeats has been associated with greater exercise performance outcomes, and the degree of, and time to, parasympathetic recovery has been used as a predictor of exercise and/or sport “readiness” (i.e., recovered system; Föhr et al., 2017; Sandercock, Bromley, & Brodie, 2005). In addition, evidence shows that regular exercisers have greater cardiac vagal tone when compared to sedentary or less-active individuals (Routledge, Campbell, & McFetridge-Durdle, 2010), suggesting this biological disposition can potentially be improved. However, it is unknown how tonic vagal tone predicts affective reactivity and recovery to exercise, or how phasic vagal tone may be associated with state-dependent changes in affective responses to exercise.

2.4 Individual Differences

The conceptualization of mind-body separation is long outdated, as evidence suggests that individual differences, such as personality traits and motivations, play a significant role in physiological and psychological responses. More specifically, dimensions of personality have been examined in order to provide further understanding of exercise behavior (i.e., initiation and adherence), affective responses (i.e., how one feels), and the relationship with neural (frontal cortical) activity (Courneya & Hellsten, 1998; Schmidtke & Heller, 2004; Wilson & Dishman, 2015).

During the 20th century, personality psychologists determined an emergence of five, broad, consistent personality dimensions, now referred to as the "Big Five" or the Five Factor Model (Goldberg, 1993, John & Srivastava, 1999; McCrae & Costa, 1987). These factors (i.e., personality dimensions), based on the various individual characteristic adjectives, are Extraversion, Neuroticism, Openness to experience, Agreeableness, and Conscientiousness (see Goldberg, 1993). Not surprisingly, as personality encompasses various trait characteristics that influence an individual's perception and reaction to various stimuli, certain personality dimensions have been linked to exercise engagement (Allen & Laborde, 2014; Box, Feito, Brown, & Petruzzello, 2019; Courneya & Hellsten, 1998; Rhodes & Smith, 2006). Allen and Laborde (2014) discussed that greater athletic performance is observed in individuals with greater Conscientiousness and Emotional Stability (conceptual opposite of Neuroticism), in addition to a tendency toward greater Agreeableness. Similarly, greater Extraversion, Conscientiousness, Openness to experience, and Emotional Stability were related to greater physical activity or health-related exercise engagement (Allen & Laborde, 2014). Courneya and Hellsten (1998) completed an investigation of personality (Big Five) and exercise behavior (exercise intensity, frequency, and adherence) and reported Neuroticism to be inversely related to more strenuous exercise intensity behavior and exercise adherence, while Extraversion and Conscientiousness were positively associated with strenuous exercise and adherence. In general, the personality dimensions Extraversion, Neuroticism, and Conscientiousness are most associated with exercise adherence and behavior, while Openness to experience and Agreeableness are related to more specific factors of exercise behavior, and tend to be less influential. However, when examining the Big Five in regular exercisers, Box et al. (2019) did not observe any traits differentiating those preferring various exercise modes, suggesting that the Big Five dimensions may be predictive of those who choose to engage in exercise or not, but does not provide insight into exercise mode choice. It is also important to consider that any observed relationships between personality dimensions and exercise behavior are likely bidirectional. That is, not only are individuals more inclined to participate in physical activity behaviors due to their personality, but their personality may also be influenced by their physical activity engagement (Allen & Laborde, 2014).

In addition to the Big Five personality dimensions, and due to the variance in exercise intensities that individuals tend to engage in, Ekkekakis, Hall, and Petruzzello (2005a) developed a self-report scale (i.e., Preference for and Tolerance of the Intensity of Exercise Questionnaire) to quantify individual differences in exercise intensity preference and tolerance. The conceptualization of these trait dimensions was completed with the understanding that not all individuals engage in high-intensity exercise; in actuality, many individuals have an aversion to high-intensity exercise (Ekkekakis, Hall, & Petruzzello, 2005a; Ekkekakis, Lind, & Joens-Matre, 2006; Hall, Petruzzello, Ekkekakis, Miller, & Bixby, 2014). However, some do choose to initiate and adhere to high-intensity exercise programs. Exercise intensity tolerance has been defined as a trait that influences one's ability to continue to exercise even when experiencing discomfort or displeasure, while intensity-preference reflects an individual's innate desire to engage in high-intensity exercise (Ekkekakis, Lind, Hall & Petruzzello, 2007). In exploring such factors, Hall, Petruzzello, Ekkekakis, Miller, and Bixby (2014) observed those with higher exercise intensity preference and tolerance traits continued for a longer period of time during a graded exercise test after reaching their anaerobic threshold. This evidence is suggestive of mediating trait variables on exercise performance, and, potentially, affective reactivity due to their ability to withstand these oppositional symptoms independent of their physical capacity. In support, Box and Petruzzello (2019) observed that those with higher intensity preference and tolerance reported more positive feeling states during a high-intensity circuit compared to their lower-intensity preference and tolerance counterparts. As such, it is of great interest to determine the extent to which these personality traits mediate affective reactivity during high-intensity exercise.

In addition to individual differences in personality dimensions, many individuals differ in their exercise motives and behavior-regulation styles. Participatory motives, the reasons why individuals engage (or would engage) in a behavior, have been linked to physical activity adherence and dropout rates (Fisher, Sales, Carlson, & Steele, 2016; Ingledew, Markland, & Medley, 1998). To explore these reasons for exercise engagement, Self-Determination Theory (SDT) is commonly applied. SDT emphasizes that individuals have three “basic needs”: 1) autonomy or sense of control/choice in behavior; 2) mastery/competence or perceived ability to successfully complete behavior; and 3) relatedness or social connectedness with those engaging in same or similar behaviors. It is posited that these three basic needs must be satisfied in order for an individual to continue engaging in a behavior (Ryan & Deci, 2000; Deci & Ryan, 2002, 2008a, b). Regulation style, an individual’s tendency to behave independent or dependent of external stimuli, is directly related to the first basic need (autonomy). Behavior regulation has been broken down into several motivation styles, from high external to high internal regulation (Ingledew & Markland, 2008). The motivation-regulation styles include, but are not limited to, amotivation (a lack of motivation), external (highly dependent on external rewards/avoiding punishment), introjected/identified (dependent on external rewards and dependent on self-satisfaction), and integrated/intrinsic (highly dependent on self-satisfaction) regulation (Ingledew & Markland, 2008), where a greater tendency towards internal regulation is associated with more autonomous motivation (Ryan & Deci, 2000). In the exercise-domain, the basic need for autonomy, associated with greater intrinsic regulation, has been linked to greater intention and engagement in exercise behavior (Ingledew & Markland, 2008; Wilson, Rodgers, Loitz, & Scime, 2006). As such, it is expected that individuals with more autonomous/intrinsic motivations will engage in greater exercise behavior. Previous work has shown that individuals who indicate greater enjoyment, satisfaction, and self-fulfillment (i.e., intrinsic motives) were more likely to engage in exercise with greater frequency and duration, as well as adhere to their exercise regimen longer (Box et al., 2019, Box, Feito, Brown, Heinrich, & Petruzzello, 2019; Heinrich, Patel, O'Neal, & Heinrich, 2014; Wilson, Rodgers, Loitz, & Scime, 2006). On the other hand, an individual with a controlled regulation style is more motivated by extrinsic participatory motives (e.g., to gain reward, avoid punishment). Participatory motives and regulatory styles are distinct, but are highly associated with each other (see Figure 2.2).

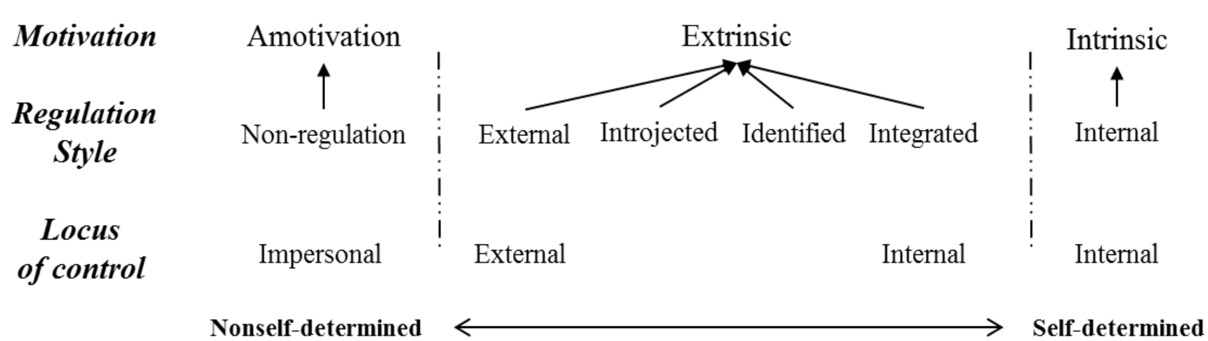

Figure 2.2. Motivation and regulation as posited by the Self-Determination Theory. (**Note**. Illustration adapted from Deci and Ryan (2002, pg. 72, Figure 1)).

Due to the significant impact of individual difference variability on exercise outcomes, it is important to consider individual differences as antecedents to exercise behavior, and how these differences mediate affective reactivity and recovery.

2.5 The Person *Forms* the Response

As emotional, thoughtful, and social creatures, humans have innate tendencies (e.g., personality traits, motivations, behavior-regulation styles) to respond to a stressor (e.g., high-intensity exercise) in a particular way (e.g., change in feeling states). These inherent responses may be compromised (e.g., declines in feeling states) or optimized (e.g., inclines in feeling states) given consideration of other existing variables (e.g., presence of emotional distraction, emotional disorders, prior exercise experience, fitness levels, pre-stimulus stress-load). Thus, and although comparisons of affective responses to continuous high-, moderate-, and light-intensity exercise have been well-examined with the typical trend of high-intensity exercise resulting in less pleasant (or even unpleasant) affective states, it is curious why some individuals choose to initiate and continue a high-intensity exercise regimen. Perhaps for some, the "stage is set" for optimized affective responses during high-intensity exercise at first attempt (i.e., initiation), which may promote future attempts at high-intensity exercise. It is likely some of these individuals remain in an optimized "pre- high-intensity exercise state" and adhere to high-intensity exercise programming, while others may be confounded by other variables (e.g., emotional, social external stressor) which set the stage for compromised affective states (i.e., negative reactivity) during high-intensity exercise. Determining the existing variables prior to exercise engagement that alter affective change during high-intensity exercise may lead to further understanding of the high-intensity training trend. Evidence supports the hypothesis that in-task exercise affect is associated with future exercise engagement, where less pleasant states (commonly elicited by high-intensity exercise) are associated with greater exercise drop-out and more pleasant states are associated with greater adherence (Brand & Ekkekakis, 2018; Rhodes & Kates, 2015; Williams, 2008). However, as high-intensity interval training has ranked among the top fitness trends for the past several years (Thompson, 2018), this presents a paradox. With initial steps at unraveling this conundrum, evidence suggests that fitness level and trait differences are mediating affective reactivity, where those who are more fit and have a trait tendency to prefer and tolerate high-intensity exercise respond more positively (Box & Petruzzello, 2019; Ekkekakis & Petruzzello, 1999). However, individual trait (e.g., personality, behavior-regulation) and exercise behavior (e.g., regular mode, intensity engagement) differences are generally less understood as precursors of affective change during a high-intensity exercise bout, and deserve to be explored. In addition to the potential, influential role of individual differences, pre-exercise psychophysiological states are likely to significantly influence affective reactivity and recovery. For example, greater perceived and physiological stress prior to an acute bout of exercise may have undue influence on negative affective reactivity, and may be associated with lessened exercise enjoyment or affective recall. Additionally, an individual may have a biological disposition to respond more negatively to a "stressful" stimulus, such as high-intensity exercise. As such, considering the relationships between these individual differences, but also determining how and to what extent these differences produce variance in affective change to high-intensity exercise, seems appropriate. This leads to the present study's second aim, namely to explore how (and to what extent) personality traits (e.g., exercise intensity preference and tolerance, extraversion, neuroticism, & conscientiousness) and biological dispositions (i.e., vagal tone) influence affective reactivity and recovery.

CHAPTER 3: METHODS & MATERIALS

3.1 Participants

Participants (see Table 3.1 for participant characteristics) were recruited via word of mouth and posted flyers for a study exploring differences associated with individual characteristics unique to exercise (e.g., variable cardiorespiratory fitness and exercise modes). Participants who responded to recruitment materials had to meet physical activity guidelines (≥ 150-minutes of moderate-intensity exercise/week or ≥ 75-minutes of high-intensity exercise/week) most weeks (>85%) for the past 6-months to be included. Participants were excluded if they selected "Yes" for any question on the Physical Activity Readiness Questionnaire (PAR-Q^+; Warburton, Jamnik, Bredin, & Gledhill, 2011) or Health History Form (see Appendix). All participants provided informed consent and information on handedness (e.g., only right-hand dominant were included) prior to completing any study session.

Table 3.1
Participant Characteristics

Sample (*N*)	25
Sex (*n, % female*)	13, 52%
Age (*M*±*SD*)	23.32±4.02
BMI Categories (*n, %*)	
Normal	14, 56%
Overweight	6, 24%
Class I Obese	3, 12%
Class II Obese	2, 8%
ACSM Fitness Categories* (*n, %*)	
Excellent	5, 20%
Good	6, 24%
Fair	6, 24%
Poor	6, 24%
Very Poor	2, 8%
Primary Mode of Exercise (*n, %*)	
Resistance Training	8, 33.3%
Aerobic Exercise	12, 50%
Other (HIIT, CrossFit® training)	4, 16.7%

Note. *ACSM Fitness Categories (ACSM, 2017, pp. 93-94)

3.2 Experimental Design

The present study consisted of four testing days: (1) a baseline session, (2) a graded exercise test, and (3 & 4) two exercise (high- and moderate-intensity) conditions. All sessions were separated by at least 24-hours, with no more than 1 week between subsequent sessions, and all participants were scheduled at the same time of day (±1-hour start-time). As participants were aware they would be completing both a high- and moderate-intensity interval exercise condition, sessions 3 and 4 were counterbalanced in order to better control pre-exercise responses, and they remained blind to the condition completed. The present study was approved by the University of Illinois Institutional Review Board before participant recruitment.

3.3 Measures

Past/Current Exercise Behavior Questionnaires

In order to determine the level of past and/or current exercise behavior (i.e., mode, intensity, duration, and length of participation), the following researcher-developed questions were posed:

1. What is your primary mode of exercise (select from aerobic, resistance, group exercise, CrossFit training, Sport, or write-in response)?
2. In a given week, how frequently do you participate in this form of exercise (days/week)?
3. What is the average duration of each workout?
4. How long have you participated in this exercise form?

<u>Individual Trait Questionnaires</u>

Reliability analysis (Cronbach's alpha) for the following trait questionnaires can be found in Table 4.11.

Participants completed the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q). The PRETIE-Q is a 16-item survey, rated on a 5-point Likert-scale (1= “I totally disagree”, 3 = “neither agree or disagree”, 5= “I totally agree”), that assesses trait differences in exercise intensity preference (8 items) and exercise intensity tolerance (8 items; Ekkekakis, Hall, & Petruzzello, 2005a). The eight items for each subscale are summed for a total subscale score.

The Big Five Inventory (BFI) is a 44-item questionnaire which measures the personality factors proposed within the Five Factor Model; it has been shown to be both valid and reliable (Goldberg, 1993; John & Srivastava, 1999). Each of the five factors (Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness) is assessed with 8-10 items, rated on a 5-point Likert-scale (1= “disagree strongly”, 3 = “neither agree nor disagree”, 5= “agree strongly”). The items are counterbalanced so that some items need to be reverse-scored (e.g., the Extraversion item “is reserved” counterbalances the item “is outgoing, sociable”) before deriving a total subscale score. The items for each subscale are summed and averaged to determine an overall score for each factor.

The Behavioral Inhibition/Behavioral Activation System (BIS/BAS), a validated and reliable psychometric tool, uses a 4-point Likert scale (1= “strongly agree”, 4= “strongly disagree”) to assess an individual’s tendency to be more approach versus withdrawal motivated (Carver & White, 1994). The BIS (withdrawal) has been posited as a system that inhibits behavior while also increasing arousal and attention toward a particular stimulus, while the BAS (approach) reflects behavior that is meant to promote reward and avoid punishment (Harmon-Jones & Gable, 2018).

The Behavioral Regulation in Exercise Questionnaire (BREQ-3; Markland & Tobin, 2004; Mullan & Markland, 1997; Wilson, Rodgers, Loitz, & Scime, 2006), which includes six styles of behavior regulation (amotivation, external, introjected, identified, integrated, and intrinsic regulation), was completed by all participants to determine extent of exercise behavior autonomy. Each regulation style has four items rated on a 5-point Likert-scale (1= "not true for me", 3 = "sometimes true for me", 5 = "very true for me"). The BREQ-3 supplies mean scores for each regulation style, where each style reflects the continuum of self-determination (or autonomous behavior).

<u>Additional Measures</u>

Two additional questionnaires were used to assess for levels of affective disorders and for general perceptions of stress. The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983), is a 14-item questionnaire which uses a 4-point Likert-scale (individual item score range 0-3). This provides a score for Depression (via 7-items; subset range 0-21) and Anxiety (via 7-items; subset range 0-21). The total score for both Depression and Anxiety is then categorized as either normal (range 0-7), borderline abnormal (range 8-10), or abnormal (range 11-21). The Perceived Stress Scale (PSS), a 10-item Likert-style (0= "never", 2= "sometimes", 4= "very often") questionnaire (Cohen, Kamarack, & Mermelstein, 1983), was modified to assess level of stress within the past week (i.e., instead of during the past month). After reversing the "positively-worded" items, all items were summed for a total score (range 0-40), where a greater score is indicative of greater levels of perceived stress.

<u>Affective Measures</u>

Participants completed the Feeling Scale [FS, a single item scale ranging from -5 (very bad) to +5 (very good)], to assess affective valence (Hardy & Rejeski, 1989; Rejeski, Best, Griffith, & Kenney, 1987). The Felt Arousal Scale [FAS; a single item measure ranging from 1 (low activation) to 6 (high activation)] was used to assess perceptions of physiological activation (e.g., perceptions of a rapid heartbeat; Svebak & Murgatroyd, 1985). The combination of valence and activation provide a 2-dimensional scope of core affect.

The Activation Deactivation Adjective Check List (AD ACL; Thayer, 1986) was used to assess specific affective state reactivity and recovery. The AD ACL is comprised of 20-items, with five items for each of four subscales: Energy, Tiredness, Calmness, and Tension. Each item is rated on a 4-point rating scale (4= “definitely feel”, 3= “feel slightly”, 2= “cannot decide”, 1= “definitely do not feel”) with the instructions to base the response on how “you feel right now”.

To determine exercise stress fluctuations, a single, 10-point visual-stress analog scale (SAS; 1= “no stress at all”, 10= “as stressed as can be”) was provided during the exercise intervals. Participants were also asked to complete the Physical Activity Enjoyment Scale (PACES) following (5-minutes post) the exercise conditions. The PACES is an 18-item (Likert-style with bipolar anchors) questionnaire that has been deemed a valid tool for measuring activity enjoyment (Kendzierski & DeCarlo, 1991).

Perceived Exertion and Satisfaction

Borg’s (1982) Rating of Perceived Exertion [RPE; a single-item scale ranging from 6 (no exertion) to 20 (maximal exertion)], was used to assess perceptions of exertion during the exercise intervals.

Researcher-developed questions were used to assess relative satisfaction (Q1: Overall, how satisfied are you with your performance during today's exercise (1= “not satisfied at all”, 10= “as satisfied as can be”)?) and exercise-reflection (Q2: Compared to your typical exercise, do you believe that you exercised easier or harder today (1= “much easier than typical”, 10=

"much harder than usual")?) from the exercise conditions. Both questions were designed as a single-item, 10-point Likert-scale.

3.4 Protocol

For Session 1 (baseline), after explanation of study design and attainment of written consent, height (m) and weight (kg) were recorded, and body mass index (BMI) was calculated ($kg \cdot m^{-2}$). Participants were then fitted with a chest strap heart rate monitor (180° eMotion Faros, United States). They were asked to sit quietly for 8-minutes to acquire baseline measurements of vagal tone. Following this, participants were asked to complete a questionnaire battery assessing various affective states and individual traits.

Session 2 included a graded exercise test, and, upon arrival to the research laboratory, participants were fitted with a portable metabolic breathing-mask and harness (Cosmed K^5, United Kingdom) and a heart rate monitor strap (180° eMotion Faros, United States). They then began the graded exercise test on a Lode Corival CPET Cycle Ergometer (Lode, Netherlands). A 25-Watt Ramp Protocol was used (i.e., power increased by an increment of 25 Watts each minute) and progressed until volitional exhaustion, where measures of peak (i.e., highest value) oxygen consumption (VO_{2peak}) and peak heart rate (HR_{peak}) were determined. Participants then completed a 5-minute, self-selected (i.e., pedaling speed) cool down while remaining on the bike.

For sessions 3 and 4 (interval exercise conditions), participants completed the high- and moderate-intensity exercise sessions in a counterbalanced design. All participants completed both a high- and moderate-intensity session, but were randomized as to which intensity condition was completed first. Regardless of intensity condition, participants completed the same procedures for both the third and fourth sessions. Upon arrival to the research laboratory, participants were fitted with the heart monitor chest strap, asked to sit quietly for 8-minutes for recording of resting cardiac vagal tone response and completed pre-assessment questionnaires (i.e., FS, FAS, SAS, AD ACL). Participants were then fitted with the metabolic breathing-mask and harness (similar to session 2) and completed a 3-minute warm-up at a self-selected speed (at standard 50 Watts) on a Lode cycle ergometer. Following the warm-up, a predetermined load was applied to the ergometer. This load was determined from participants' graded exercise test (GXT) response, where the high-intensity condition load was set as 5% below the load of the last stage completed prior to reaching ventilatory threshold (VT; point at which expelled VCO_2 consistently exceeded consumed VO_2), and the moderate-intensity load was 25% below VT. Participants then completed 15-minutes of interval exercise (3-min exercise: 1-min rest for 5 blocks) on the cycle ergometer within the predetermined intensity range (Figure 3.1). Every 3-minutes, participants stopped pedaling and remained as still as possible for approximately 1-minute while cardiac vagal tone was recorded. Affective states, perceived stress, and perceived exertion (via FS, FAS, SAS, and RPE, respectively) were recorded within the first and last 15 seconds of each 3-min exercise interval. FS, FAS, SAS, and the AD-ACL were also recorded immediately following cessation (within 30 seconds) of each exercise bout. Heart rate and oxygen consumption were recorded continuously during each of the exercise conditions. Following cessation, participants completed additional questionnaires gauging enjoyment, satisfaction, exercise reflection (at 5-min post), and affective reactivity to the exercise conditions for 30-minutes of recovery (assessed every 5-minutes).

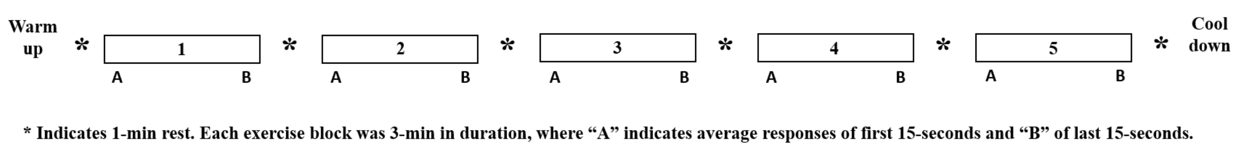

Figure 3.1. Depiction of HIIE and MIIE sessions.

CHAPTER 4: RESULTS

4.1 Interval Intensities

Purpose & Hypotheses

The purpose of this study was to determine the differences in relative physiological and perceived intensity experienced during moderate-intensity interval exercise (MIIE) and high intensity interval exercise (HIIE). Additionally, a goal was to highlight the discrepancies in relative intensities based on American College of Sports Medicine cardiorespiratory exercise standards (ACSM, 2018, pg. 146). Thus, it was hypothesized that: 1) the 'high' intensity condition would result in greater relative intensity via heart rate (%HR_{peak}), oxygen consumption (%VO_{2peak}), and perceived exertion (RPE) compared to the 'moderate' intensity condition; and 2) perceived exertion (i.e., RPE) would be lesser when compared to the physiological markers (i.e., %HR_{peak} & %VO_{2peak}) of intensity for these regular exercisers.

Statistical Analyses

Separate 2 (Condition) x 10 (Time) Repeated Measures of Analyses of Variance (RMANOVA) were conducted to determine differences in Heart Rate (HR), relative oxygen consumption (VO_2; $ml \cdot min^{-1} \cdot kg^{-1}$), and rating of perceived exertion (RPE) between the MIIE and HIIE conditions during the first and last 15 seconds of each exercise-interval. Additionally, Cohen's *d* values are reported in order to provide magnitude of difference at each time point for each relative intensity variable. Finally, Pearson's correlations were performed to explore relationships among self-report behavior and relative intensity variables. All analyses were completed using SPSS (SPSS Version 24), and alpha was set to .05 to denote significance.

Results

Analysis revealed significant Condition x Time interactions for RPE (λ= .144, F(9, 10)= 10.397, p<.001, η_p^2= .886), VO_2 (λ= .189, F(9, 10)= 4.775, p= .011, η_p^2= .811), and HR (F(9, 10)= 9.929, p< .001, η_p^2=.554). All intensity variables (RPE, $\%HR_{peak}$, & $\%VO_{2peak}$) increased from beginning (A, first 15 seconds) to end (B, last 15 seconds) of each exercise-interval for both conditions. The HIIE condition resulted in greater reported and recorded relative intensity variables across time, except for the beginning of interval 1 (i.e., 1A), when compared to the MIIE condition. See Table 4.1 for Condition x Time comparison details.

Perceived exertion (RPE), $\%HR_{peak}$, and $\%VO_{2peak}$ were calculated within the first 15 (A) and last 15 (B) seconds of each interval block and then compared to the ACSM estimation of cardiorespiratory intensity (ACSM, 2019). These relative intensity values, which can be observed in Figure 4.1, suggest the two exercise conditions were perceived (via RPE, left-most panel) as “moderate” and “vigorous” intensity conditions. In contrast, the physiological responses are suggestive of “moderate-to-vigorous” and “vigorous-to-maximal” intensity conditions as the exercise-interval(s) continued.

Table 4.1

Intensity Differences between the High- (HIIE) and Moderate-Intensity (MIIE) Exercise Conditions

		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
	HIIE	10.7±1.8	13.8±1.9	12.4±1.6	15.1±2.1	12.7±2.3	15.8±2.2	13.3±2.3	16.2±2.6	13.8±2.6	15.9±3.5
RPE	MIIE	10.0±1.5	12.2±1.2	11.1±1.2	12.5±1.6	11.2±1.5	12.6±1.7	11.3±1.8	12.8±2.0	11.5±2.2	13.3±2.2
	d	.43	**1.0**	**.94**	**1.4**	**.79**	**1.7**	**.99**	**1.5**	**.98**	**.91**
	HIIE	89.2±11.3	157.9±11.3	133.6±18.5	167.9±11.1	142.1±17.6	173.5±11.8	144.7±18.1	175.4±11.4	147.8±16.5	176.6±10.9
HR	MIIE	96.2±13.0	142.7±10.9	114.8±14.0	149.5±11.5	119.7±15.0	152.9±14.4	126.5±14.5	155.6±14.9	130.1±14.7	156.8±14.5
	d	**-.58**	**1.4**	**1.2**	**1.7**	**1.5**	**1.6**	**1.2**	**1.5**	**1.2**	**1.5**
	HIIE	14.6±4.2	33.0±7.3	18.1±3.5	34.9±7.5	19.6±3.2	35.2±7.4	20.4±4.4	35.4±8.2	20.0±3.8	36.6±8.4
VO_2	MIIE	12.5±2.8	27.4±5.8	16.3±3.7	28.7±6.1	17.1±3.6	28.6±6.1	16.6±3.7	28.4±6.2	17.4±4.0	29.4±6.2
	d	**.60**	**.87**	**.51**	**.93**	**.75**	**1.0**	**.96**	**.99**	**.69**	**1.0**

Note. Means and standard deviations (*M*±*SD*) are reported for each relative intensity variable along with estimated magnitude of difference (effect size; Cohen's *d)* between conditions, where significant differences ($p < .05$) are denoted by a bolded *d.*

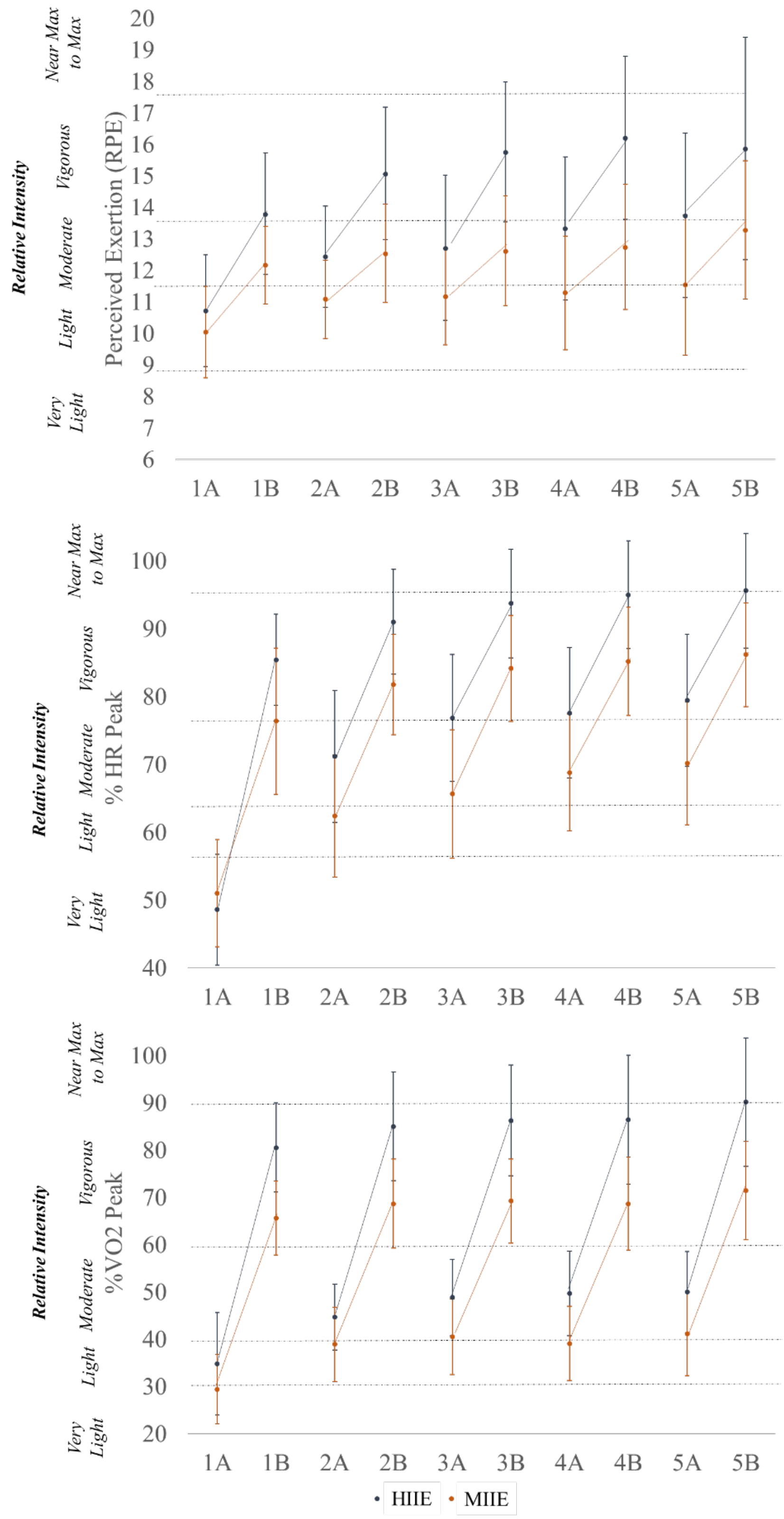

Figure 4.1. Estimated relative intensity for moderate- and high-intensity intervals. (***Note***. Participants completed 5, 3-minute exercise-intervals within each condition, where values are reported for the first (A) and last (B) 15-seconds of each of the 5, 3-minute intervals).

Discussion

Relative exercise intensity can be measured and expressed in various ways. The American College of Sports Medicine has provided a means of basing estimated intensity from several of these perceptual and physiological measures in order for cross-study comparisons to be made (ACSM, 2019). However, relying too heavily on only one variable, especially perceived exertion (i.e., RPE), may not be sufficient. The present findings suggest that perceived exertion levels were not reflective (i.e., RPE values reflected lower perceived intensity) of the relative exercise intensity when compared to physiological responses, such as $\%HR_{peak}$ and $\%VO_{2peak}$. This "lower" perceived exertion when compared to physiological markers of intensity is not atypical for regular exercisers like the participants in the present study, as Skatrud-Mickelson, Benson, Hannon, and Askew (2011) observed regular exercisers underestimated their perceived exertion (via RPE) when compared to their metabolic equivalents derived from accelerometers.

In attempting to confirm the performed exercise intensities within the two conditions, it was observed that participants completed a bout of moderate-to-vigorous (instead of moderate) intensity interval exercise and a bout of vigorous-to-maximal (instead of vigorous) intensity interval exercise. Based on relative heart rates and levels of oxygen consumption, even though ratings of perceived exertion would suggest participants performed a moderate-intensity and a vigorous-intensity interval exercise condition, the actual intensities were greater. Regardless, participants performed at a significantly greater intensity for the vigorous-to-maximal intensity interval across time (with the exception of the first 3-min interval) when compared to the moderate-vigorous interval exercise.

The importance of verifying the intensity performed cannot be understated, especially as it relates to the perceptual and physiological responses of interest. The present study was designed to control exercise duration and mode, thus providing a potential means of strong inference of exercise-interval-intensity reactivity. However, due to the performed intensities being more taxing than anticipated, any responses (affective, cardiovascular) that occurred should be considered and explained from the perspective of the relative intensity performed (i.e., moderate-to-vigorous and vigorous-to-maximal intensity), rather than the intensity proposed (i.e., moderate- and high- intensity).

4.2 Affective Intervals

Purpose & Hypotheses

The purpose of this study was to explore the affective reactivity and recovery associated with high-intensity interval exercise in comparison to moderate-intensity interval exercise. In order to explore these responses, core affect (i.e., valence, activation), emotional states (i.e., Energy, Tiredness, Tension, & Calmness), perceived stress, enjoyment, and satisfaction were all assessed before, during, and/or following a moderate- and high-intensity interval exercise condition. A large body of evidence suggests high-intensity exercise will result in affective declines during exercise, with a rebound in these feeling states immediately upon exercise cessation (Acevedo, Kraemer, Haltom, & Tryniecki, 2003; Ekkekakis, Hall, & Petruzzello, 2005b, 2008; Ekkekakis, Parfitt, & Petruzzello, 2011; Ekkekakis & Petruzzello, 1999). It was hypothesized that: 1) the high-intensity interval exercise (HIIE) condition would result in more negative valence (coupled with greater activation) and perceived stress during, and more Tension and Tiredness (coupled with greater declines in Calmness and Energy), less enjoyment, and more satisfaction immediately following the bout compared to the moderate-intensity interval exercise (MIIE); 2) HIIE would result in greater affective reactivity (larger declines from beginning to end of each interval), and less affective recovery (smaller increases from end to beginning of next interval); and 3) pre-exercise affective states would account for significant variance in HIIE enjoyment, satisfaction, and affective recovery.

Statistical Analyses

To test the first hypothesis, separate 2 (Condition) x 17 (Time) Repeated Measures of Analysis of Variance (RMANOVA) were conducted to determine whether any differences in Feeling Scale (FS), Felt Arousal Scale (FAS), and perceived stress (PS) occurred between the MIIE and HIIE conditions prior to (PRE), during the first and last 15 seconds of each interval, immediately post (IP), and every 5-minutes up to 30-minutes post-exercise. Separate 2 (Condition) x 4 (Time) RMANOVAs were conducted to analyze differences in Energy, Tension, Tiredness, and Calmness at PRE, IP, Post 15- and 30-minutes. A paired samples *t*-test was used to examine differences in condition enjoyment and satisfaction. Effect sizes, expressed as Cohen's *d* (*d*= 0.2, 0.5, 0.8 are considered small, moderate, and large effects, respectively; Cohen, 1988) were reported in order to provide magnitude of difference at each time point for each relative intensity variable. To examine the second hypothesis, percent change (%Δ) scores were calculated for valence from relative Pre-exercise values. Then, changes were examined from the first (A) 15- to last (B) 15-second values within each exercise-interval to determine reactivity and from the last (B) 15- to first (A) 15-second values between intervals to determine recovery. Lastly, Pearson's correlations were used to examine relationships among affective responses. In the presence of meaningful correlations, separate hierarchical regressions [Block 1 = Age, Sex, BMI, and VO_{2peak}, Block 2 = Pre-exercise valence, Block 3= Pre-exercise Energy] were conducted to explore the variance explained by pre-affective states on affective reactivity and recovery during MIIE and HIIE conditions. All analyses were completed using SPSS (SPSS for Windows, version 24.0), and alpha was set to .05 to denote significance.

Results

Moderate- and High-Intensity Interval Comparisons

RMANOVA showed that core affect (valence & activation), perceived stress, Energy, and Tension did not differ between baseline session and pre-exercise recordings. However, a Condition main effect revealed both Tiredness ($F(2, 46)= 4.452$, $p= .017$, $\eta_p^2= .162$) and Calmness ($F(2, 46)= 7.408$, $p= .002$, $\eta_p^2= .244$) differed between session days. More specifically, participants reported significantly more Tiredness before the moderate-intensity interval (MIIE; 13.1±3.4) session compared to both the baseline (11.0±3.2; $p= .018$, $d= .648$) and the high-intensity interval (HIIE) sessions (11.3±3.5; $p= .170$, $d= .539$). Conversely, participants reported less Calmness before HIIE (14.9±3.3) compared to both the baseline (16.5±2.8; $p= .003$, $d= .526$) and MIIE (16.4±3.1; $p= .009$, $d= .466$) sessions. As such, these Pre-exercise feeling state differences should be considered when interpreting Condition x Time effects.

In comparing the differences between core affect and perceived stress between exercise conditions, separate RMANOVAs revealed significant Condition x Time interactions for valence ($F(16, 320)= 7.002$, $p< .001$, $\eta_p^2= .259$), activation ($F(16, 320)= 1.719$, $p= .042$, $\eta_p^2= .079$), and perceived stress ($F(16, 320)= 8.593$, $p< .001$, $\eta_p^2= .301$). Significant differences ($p_s< .05$) in valence emerged between HIIE and MIIE at the end (i.e., last 15 seconds) of the second exercise-interval (2B) and continued through immediately-post (IP). The magnitude of this difference became larger within each successive exercise-interval and between subsequent intervals (see Table 4.2); valence returned to similar levels between conditions starting as early as 5-minutes post-exercise (see Figure 4.2). For activation, significant differences were observed at the end of the first exercise-interval (1B) and continued through 15-minutes post-exercise (see Figure 4.2). Similar to reactivity observed with affective valence, perceived stress also began to differ significantly between conditions starting at the end of the second interval (2B), where differences grew larger with successive intervals, through immediately post-exercise, where similarities began to re-emerge during recovery (see Figure 4.2).

Table 4.2

Magnitude of Effect (Cohen's *d*) in Affective States and Stress between HIIE and MIIE (*M*±*SD*) Before and During the Exercise

			Interval 1		*Interval 2*		*Interval 3*		*Interval 4*		*Interval 5*	
		PRE	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
Valence	HIIE	2.4±1.4	2.3±1.3	1.7±2.0	2.1±1.6	1.4±2.1	1.9±1.4	0.8±2.1	1.5±1.6	-0.1±2.3	1.2±2.0	0.2±2.3
	MIIE	2.4±1.3	2.0±1.3	2.0±1.5	2.2±1.4	2.2±1.6	2.6±1.5	2.2±1.9	2.6±1.5	2.1±1.8	2.5±1.5	2.4±1.7
	d	.00	.24	-.17	-.07	***-.44***	***-.49***	***-.72***	***-.73***	***-1.1***	***-.75***	***-1.1***
Activation	HIIE	2.1±1.2	2.9±1.1	4.0±1.1	3.6±1.2	4.3±1.1	3.6±1.2	4.6±1.2	3.9±1.2	4.8±1.4	3.9±1.2	4.7±1.4
	MIIE	1.8±0.9	2.5±1.3	3.4±1.0	3.1±1.0	3.7±1.1	3.1±1.4	3.7±1.2	3.1±1.2	3.7±1.2	3.2±1.3	3.9±1.2
	d	.29	.34	***.59***	***.46***	***.56***	***.39***	***.77***	***.68***	***.86***	***.57***	***.63***
Stress	HIIE	2.5±1.7	2.8±1.7	3.2±1.8	2.9±1.7	3.8±2.0	3.3±1.7	4.1±2.1	3.4±1.8	4.5±2.4	3.7±2.2	4.5±2.6
	MIIE	2.6±1.4	2.3±1.3	2.8±1.2	2.6±1.1	2.7±1.3	2.2±1.1	2.6±1.2	2.4±1.2	2.6±1.4	2.4±1.2	2.7±1.4
	d	-.07	.34	.27	.22	***.75***	***.50***	***.90***	***.67***	***.99***	***.75***	***.88***
Energy	HIIE	10.0±2.4										
	MIIE	9.3±2.8										
	d	.27										
Tension	HIIE	6.3±1.9										
	MIIE	5.5±0.7										
	d	*.57*										
Tiredness	HIIE	11.3±3.4										
	MIIE	13.1±3.4										
	d	*-.54*										
Calmness	HIIE	14.9±3.3										
	MIIE	16.4±3.1										
	d	*-.48*										

Note. All significant (p_s< .05) effects are in bolded italics. Core affect and Perceived stress were collected during each of the 5, 3-minute intervals within the first 15 seconds (indicated by "A") and last 15 seconds (indicated by "B").

Table 4.3

Magnitude of Effect (Cohen's *d*) in Affective States and Stress between HIIE and MIIE (*M*±*SD*) Following the Exercise

		IP	P5	P15	P20	P25	P30
Valence	HIIE	1.2±2.0	2.6±1.9	3.0±1.9	3.1±1.8	3.3±1.5	3.4±1.5
	MIIE	2.6±1.6	3.1±1.4	3.1±1.6	3.2±1.3	3.2±1.3	3.3±1.1
	d	***-.79***	-.31	-.06	-.07	.07	.08
Activation	HIIE	3.9±1.4	3.8±1.6	2.6±1.4	2.7±1.7	2.5±1.5	2.4±1.4
	MIIE	3.1±1.4	3.1±1.4	1.9±1.0	2.5±1.4	2.2±1.1	2.3±1.1
	d	***.59***	***.48***	***.59***	.20	.23	.08
Stress	HIIE	3.1±2.0	2.6±1.9	2.4±2.0	2.2±1.8	2.0±1.5	1.9±1.2
	MIIE	2.3±1.2	2.1±1.2	2.0±1.3	2.0±1.3	1.9±1.2	1.8±1.2
	d	***.50***	.32	.24	.13	.08	.09
Energy	HIIE	15.0±4.2		10.8±3.0			12.0±2.8
	MIIE	14.6±2.7		9.9±2.6			9.9±2.6
	d	.12		.33			***.79***
Tension	HIIE	8.7±2.8		6.8±2.6			6.2±1.5
	MIIE	6.8±2.1		5.7±0.8			5.7±0.9
	d	***.78***		***.58***			***.41***
Tiredness	HIIE	7.8±3.3		10.6±3.7			9.3±3.0
	MIIE	8.3±2.4		11.5±3.6			9.9±3.0
	d	-.18		-.25			-.20
Calmness	HIIE	10.3±3.3		14.7±2.8			13.6±3.1
	MIIE	12.5±3.2		15.8±2.8			14.9±2.8
	d	***-.69***		***-.40***			***-.45***

Note. All significant (p_s< .05) effects are in bolded italics. Core affect and Perceived stress were collected during each of the 5, 3-minute intervals within the first 15 seconds (indicated by "A") and last 15 seconds (indicated by "B")

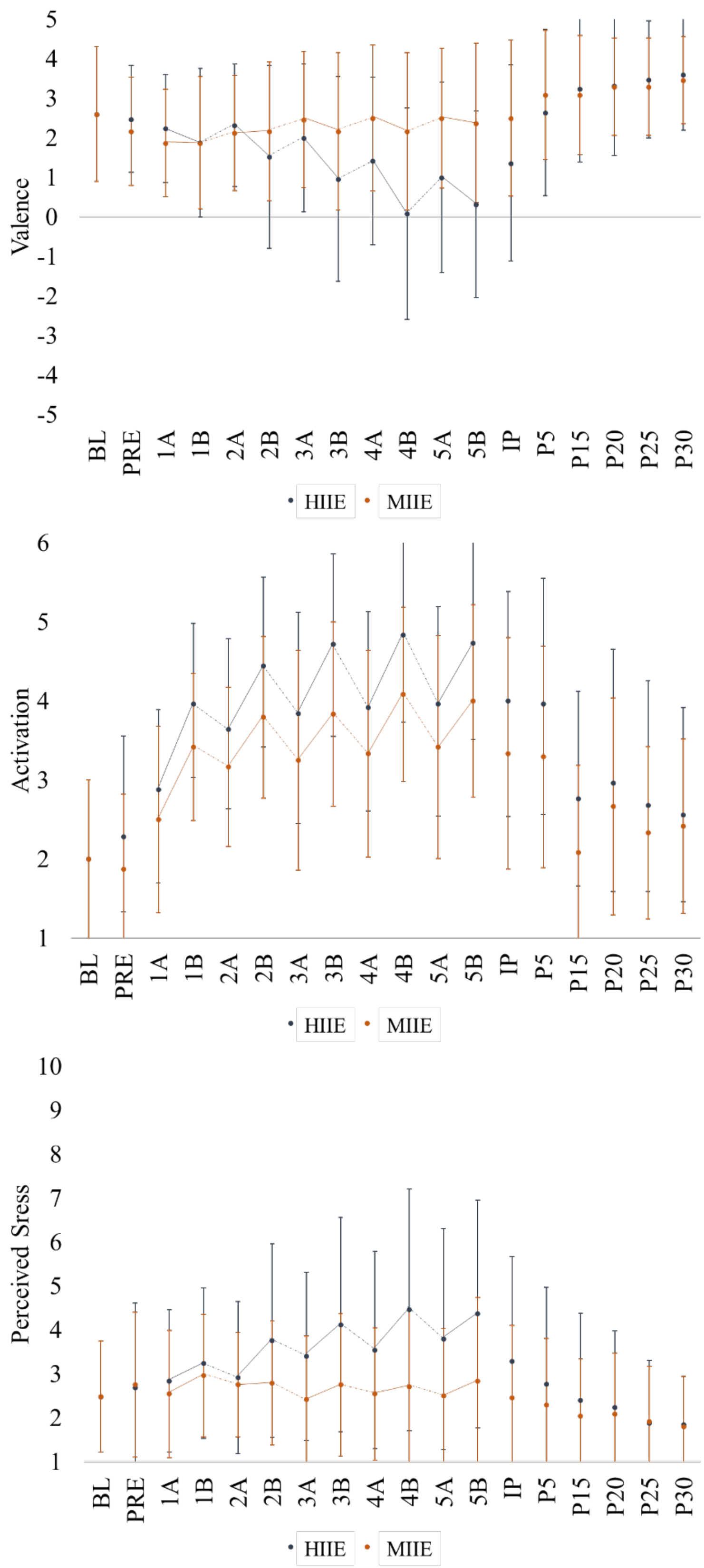

Figure 4.2 Differences in valence (a), activation (b), and stress (c) between HIIE and MIIE. (**Note.** * *p*< .05; Magnitude of effects (i.e., effect size) can be viewed in Table 4.2)

In examining whether there were differences in Energy, Tension, Tiredness, and Calmness between the HIIE and MIIE, a RMANOVA revealed significant Condition x Time interactions for Tension ($F(3, 69)= 2.808$, $p= .046$, $\eta_p^2= .109$), but not for Energy ($F(3, 69)= 2.79$, $p= .063$, $\eta_p^2= .108$), Tiredness ($F(3, 69)= 1.077$, $p= .365$, $\eta_p^2= .045$), or Calmness ($F(3, 69)= 0.604$, $p= .582$, $\eta_p^2= .026$). Tension was significantly ($p_s< .05$) greater at every time point (i.e., PRE, IP, P15, & P30) during the HIIE condition when compared to the MIIE condition (see Table 4.2). Examining the Time main effect for both conditions, Tension increased immediately post-exercise, began to decline 15-minutes post exercise(s), and returned to pre-exercise levels 30-minutes post-exercise (see Figure 4.3). Although a significant Condition x Time interaction was not observed for Energy, Tiredness, nor Calmness, the reported effect sizes are indicative of a large difference at 30-minutes post exercise between HIIE and MIIE for Energy, and moderate differences between HIIE and MIIE at each time point (see Table 4.2) for Calmness.

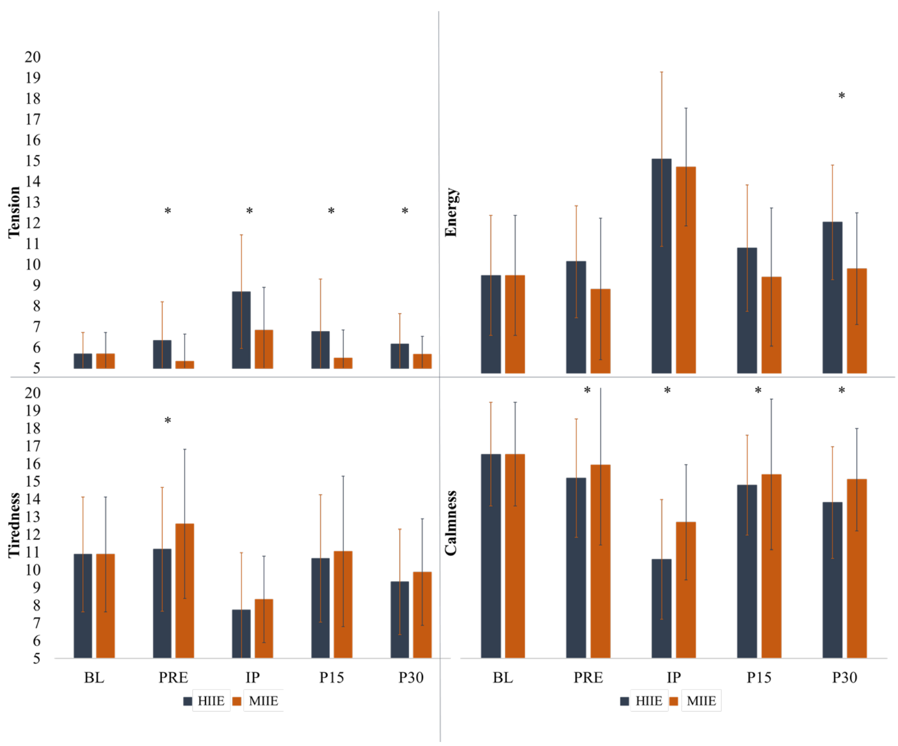

Figure 4.3 Emotional reactivity to and recovery from HIIE and MIIE.
(***Note***. *Indicates moderate-large magnitude of difference between conditions (Cohen's *d*). See Table 4.2 for specifics).

A paired-samples *t*-test revealed Enjoyment ($t(23)= -.179$, $p= .860$, $d= .02$) and Satisfaction ($t(23)= -1.94$, $p= .065$, $d= .41$) did not significantly differ between HIIE (Enjoyment= 94.4±21.3; Satisfaction= 6.8±2.5) and MIIE (Enjoyment= 94.8±20.3; Satisfaction= 7.7±2.0) conditions. However, a significant difference ($t(23)= -1.75$, $p< .001$, $d= 1.4$) was observed for Exercise-reflection between HIIE (6.5±2.1) and MIIE (4.0±1.6) conditions (see Figure 4.4).

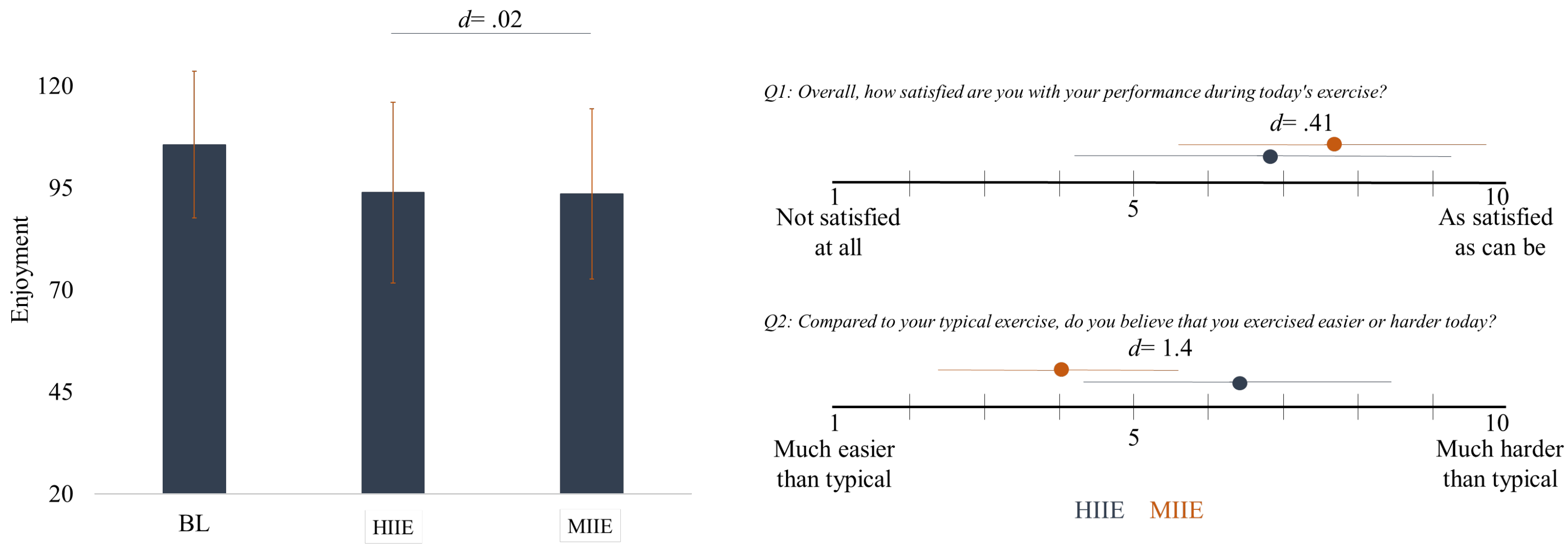

Figure 4.4 Enjoyment, satisfaction, and reflection comparisons between HIIE and MIIE.
(***Note***. Baseline (BL) Enjoyment was asked in reference to the participant's preferred exercise before partaking in the HIIE or MIIE conditions. Q1 refers to participants Satisfaction, while Q2 refers to Exercise-reflection. See text for specifics).

Exploring the Affective Interval

When exploring the affective valence reactivity and recovery changes from pre-exercise states, %Δ scores revealed that MIIE resulted in more pleasant feeling states (i.e., valence) during the exercise (except for during the first 3-min interval), with steady increases in valence (i.e., increasing pleasantness) during recovery (from 5-minutes to 30-minutes post recovery). HIIE induced large declines in affective valence (i.e., decreasing pleasantness) throughout the entire duration of the exercise, but dramatically rebounded beyond pre-exercise states as early as 5-minutes post-exercise and steadily increased through 30-minutes post exercise (see Figure 4.5).

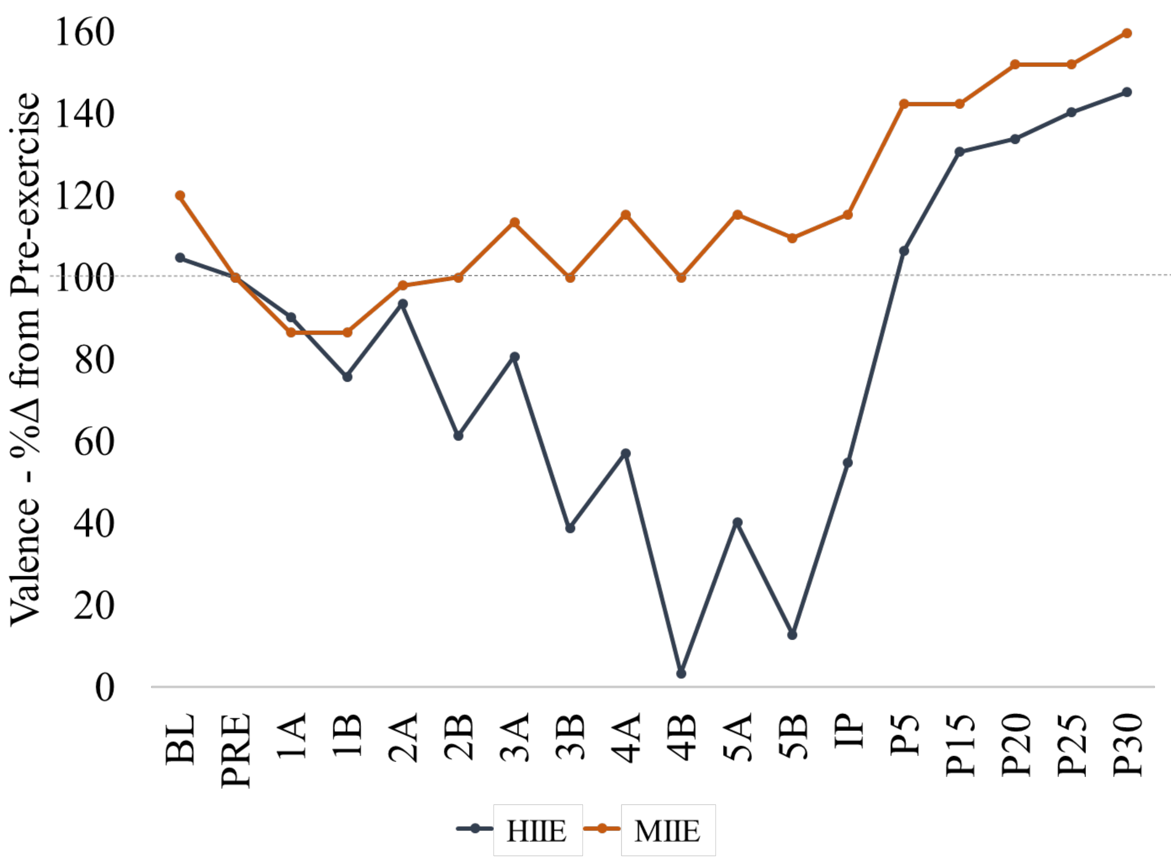

Figure 4.5. Percent change from relative pre-exercise during HIIE and MIIE. (***Note.*** Pre-exercise %Δ is equal to 100%, where scores below 100% indicate decline in pleasure, while scores about 100% indicate increase in pleasure. See Table 4.2 for valence scores).

For both HIIE and MIIE, affective valence declined slightly from pre- to the beginning of the first exercise interval (*d*= 0.18 & 0.21, respectively). Examining valence reactivity and recovery during the HIIE condition, the decline in valence became larger with each subsequent interval (Cohen's *d* for interval 1= 0.23, 2= 0.42, 3= 0.47, 4= 0.57). However, the final (fifth) interval, although still resulting in a decline in affective valence from beginning to end, did not follow this trend (interval 5= 0.29), as valence did not decline more than during the fourth-interval. This may be related to participants' awareness that exercise cessation was soon to follow. As each exercise interval resulted in affective declines, each 1-min rest period produced more pleasant feeling states (i.e., a rebound). More specifically, less pleasant states were reported when comparing the end of one interval to the beginning of the succeeding interval. Interestingly, the rebounds in valence were similar between each interval (Cohen's *d* for rest-1= 0.26, 2= 0.23, 3= 0.20, 4= 0.29). Due to the similar rebounds in affective valence following rest-periods, with the increasingly larger decline in valence across subsequent intervals, the HIIE condition resulted in an increasingly, and overall, less pleasant feeling state (see Figure 4.6).

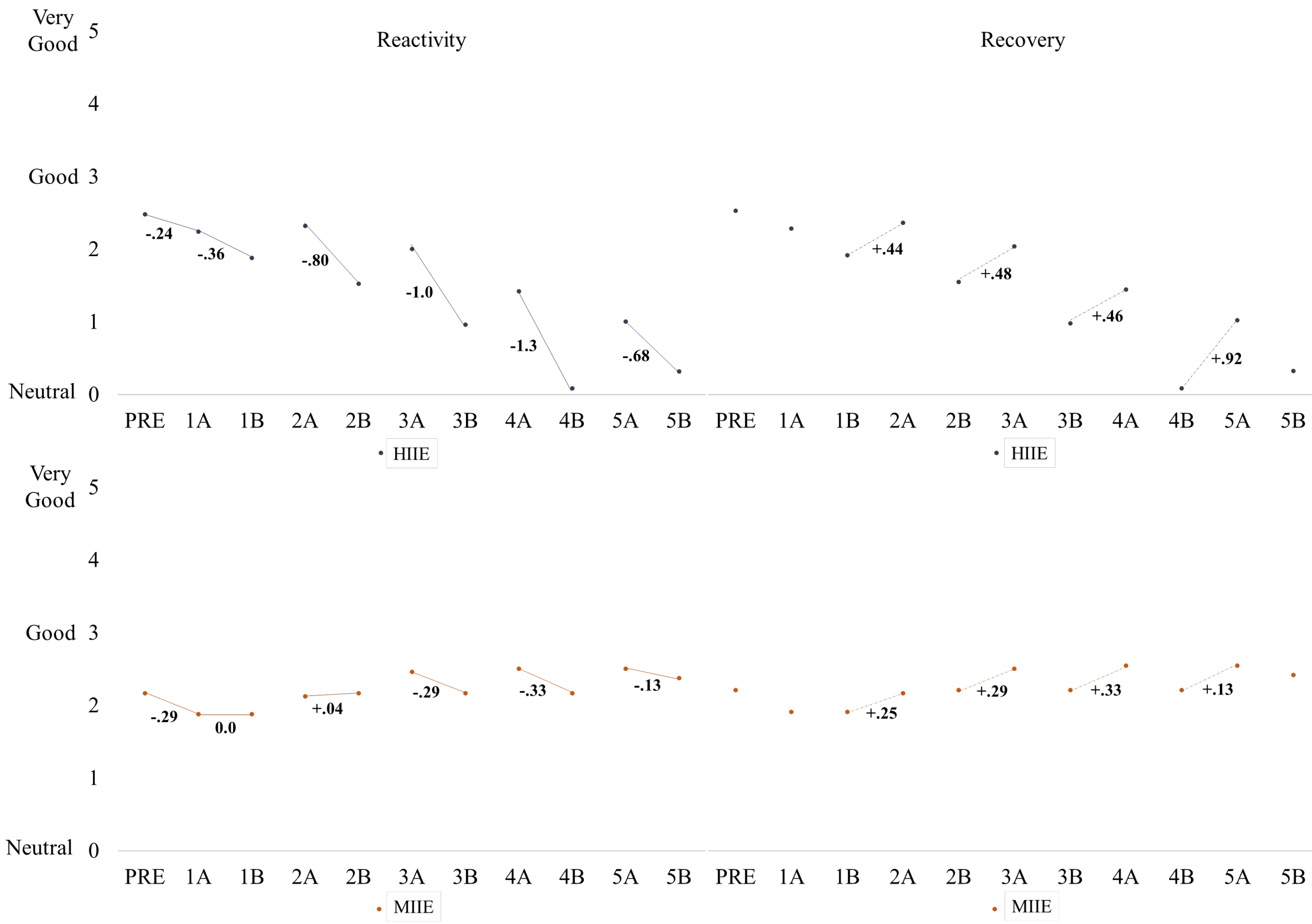

Figure 4.6. Breakdown of valence reactivity and recovery during exercise intervals. (***Note.*** Reactivity refers to changes in average valence that occur from beginning (A) to end (B) of each exercise-interval, while Recovery refers to changes from end (B) to beginning (A) of succeeding intervals. Average valence score changes [Reactivity ("B"-"A") and Recovery ("A"-"B")] are reported. See text for magnitude of change).

Unlike HIIE, the MIIE resulted in more balanced affective reactivity to each interval, where no-to-small differences were observed across intervals (Cohen's *d* for interval 1= 0.00, 2= 0.03, 3= 0.16, 4= 0.18, 5= 0.07). This was coupled with similar, more positive rebounds across rest-intervals (Cohen's *d* for rest 1= 0.16, 2= 0.17, 3= 0.18, 4= 0.18). For MIIE, the rebounds were equal or greater to any negative reactivity that occurred during the exercise-interval, resulting in an increasingly (albeit small) more pleasant feeling state overall (see Figure 4.6 for raw score changes).

Pre-exercise affective states foster exercise-affect reactivity and recovery

In determining existing relationships between pre-exercise affect and valence reactivity and recovery for HIIE, Pearson's correlations revealed significant ($p_s < .05$), positive relationships between pre-HIIE valence and Energy with various condition time points (see Table 4.4 & 4.5). More specifically, pre-exercise valence was related to reported valence at the beginning of the exercise-intervals, while pre-exercise Energy was related to exercise valence throughout the subsequent intervals, except for the final (fifth) interval. Additionally, pre-valence and Energy were related to recovery valence at 5-min, 20-min, 25-min, and 30-min post-exercise. In examining these relationships, and accounting for age, sex, body mass index (BMI), and VO_{2peak} [i.e., insignificant ($p_s > .05$) variance ($R^2_s = .006-.228$) explained; See Table 4.6], separate hierarchical regressions suggested pre-exercise valence accounted for additional unique variance in valence during the beginning of intervals 1 and 2, while pre-exercise Energy accounted for additional variance (i.e., after also considering pre-valence) at the beginning of interval 3 and the ends of intervals 2, 3, and 4 (see Figure 4.7).

Table 4.4. Correlation Matrix Between Pre-Exercise Affect and Valence Reactivity & Recovery During HIIE

Pre- HIIE	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	IP	P5	P15	P20	P25	P30
Valence	**0.61**	**0.38**	**0.62**	0.37	**0.46**	0.28	**0.43**	0.25	0.13	0.12	0.19	**0.49**	0.35	0.37	**0.48**	**0.43**
Energy	0.34	**0.51**	**0.59**	**0.58**	**0.58**	**0.58**	**0.46**	**0.54**	0.23	0.36	0.32	**0.52**	0.32	**0.40**	**0.47**	0.37
Tiredness	-0.29	-0.23	-0.37	**-0.49**	**-0.38**	-0.36	-0.36	-0.31	-0.12	-0.06	-0.13	**-0.47**	**-0.48**	-0.35	-0.36	-0.27
Tension	-0.15	-0.08	0.01	0.12	0.05	0.06	-0.01	-0.06	-0.07	-0.10	-0.05	0.07	0.09	0.18	0.18	0.13
Calmness	-0.14	-0.23	-0.20	-0.29	-0.11	-0.23	0.06	-0.05	0.04	-0.03	-0.05	-0.12	-0.09	-0.14	-0.07	-0.09

Note. Significant (p< .05) correlations are bolded.

Table 4.5 Correlation Matrix Between Pre-Exercise Affect and Affective Recovery During HIIE

Pre-HIIE	IP-Energy	IP-Tired	IP-Tense	IP-Calm	P15-Energy	P15-Tired	P15-Tense	P15-Calm	P30-Energy	P30-Tired	P30-Tense	P30-Calm
Valence	**0.38**	**-0.49**	0.09	-0.22	**0.44**	**-0.42**	-0.20	0.01	0.23	**-0.52**	-0.27	0.15
Energy	0.07	-0.17	-0.14	-0.03	**0.49**	-0.14	-0.17	-0.24	**0.41**	-0.25	0.05	-0.09
Tiredness	-0.20	**0.55**	0.15	0.14	-0.28	**0.56**	0.06	0.22	-0.28	**0.78**	0.08	-0.10
Tension	-0.36	0.13	0.12	-0.19	-0.22	0.07	0.26	**-0.43**	0.15	-0.13	**0.50**	**-0.49**
Calmness	0.31	-0.23	0.14	0.16	0.06	0.07	0.08	**0.39**	-0.16	0.10	-0.19	**0.76**

Note. Significant (p< .05) correlations are bolded.

Table 4.6 Cumulative Exercise-Valence Variance Explained

	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
HIIE	43.8%	33.5%	52.3%	43.8%	41.7%	42.8%	33.8%	35.0%	7.7%	30.0%
MIIE	64.6%	62.6%	68.4%	63.8%	65.2%	62.3%	53.2%	58.6%	47.7%	51.6%

Note. Variance explained from hierarchical regressions, where age, sex, BMI, VO_{2peak}, pre-exercise valence, and pre-exercise energy were predicting variables on exercise-affect within the beginning (A) and end (B) of the 5 exercise intervals. % scores are derived from R^2 (x100).

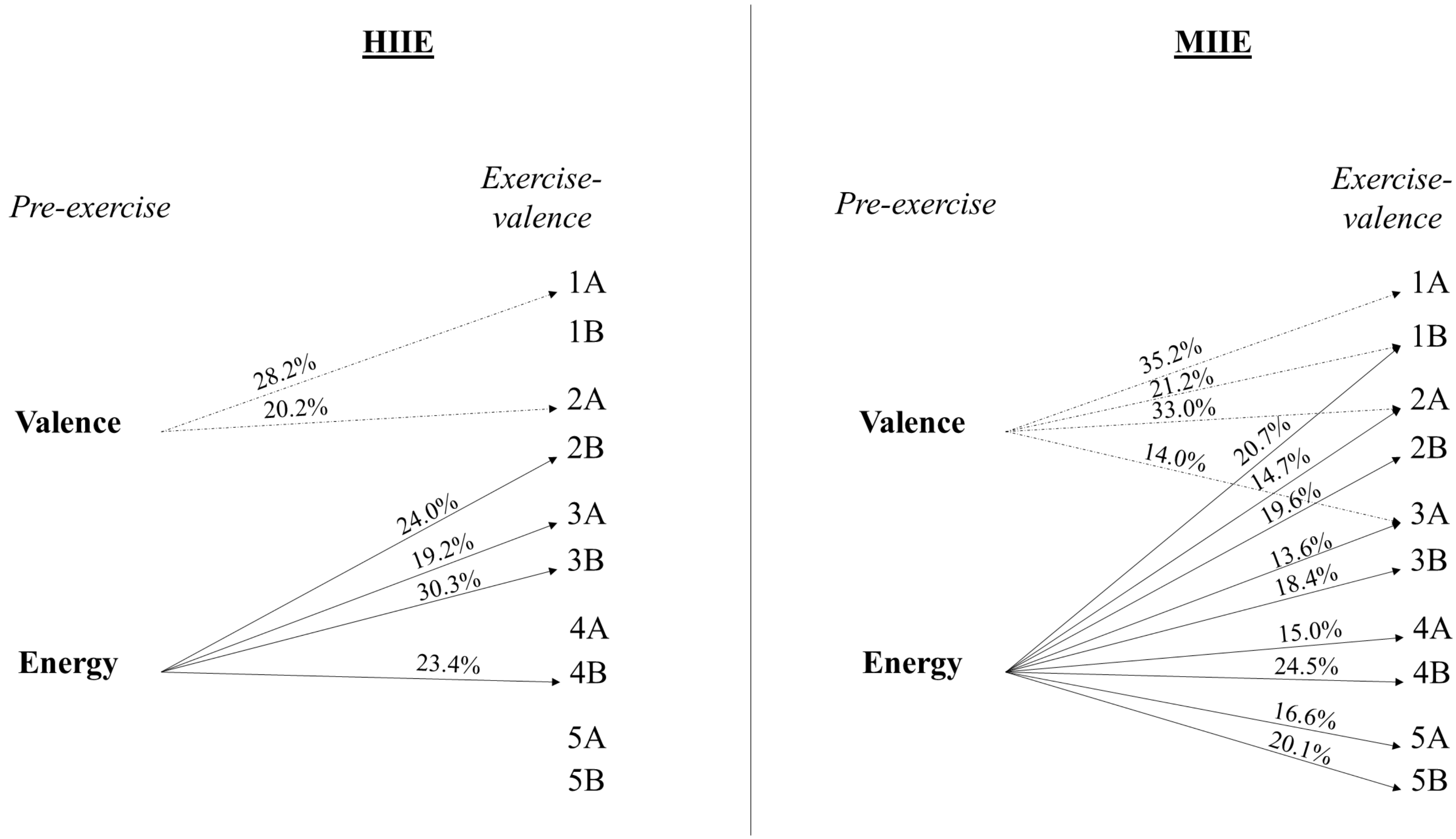

Figure 4.7 Pre-exercise valence and Energy influence interval exercise valence.

In addition, some significant ($p_s < .05$), positive relationships were seen between pre-MIIE valence and Energy with valence reactivity and recovery values (see Table 4.7 & 4.8). Significant correlations were observed for pre-valence and Energy with reported valence throughout the exercise intervals, but not for recovery values during MIIE. Using these observed relationships, separate hierarchical regressions, after accounting for age, sex, BMI, and VO_{2peak} ($R^2_s = .006$-$.228$, $p_s > .05$), revealed that pre-exercise valence explained significant unique variance in valence during the beginning of intervals 1, 2, and 3; pre- Energy explained additional variance during the beginning and end of each subsequent exercise interval, except for the beginning of the first interval (see Figure 4.7).

Table 4.7

Correlation Matrix Between Pre-Exercise Affect and Valence Reactivity & Recovery During MIIE

Pre-MIIE	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	IP	P5	P15	P20	P25	P30
Valence	**0.73**	**0.58**	**0.69**	**0.47**	**0.54**	**0.43**	**0.48**	0.31	0.30	0.35	0.34	0.36	**0.48**	0.33	0.25	0.21
Energy	**0.41**	**0.56**	**0.54**	**0.49**	**0.44**	**0.48**	**0.47**	**0.49**	**0.41**	**0.47**	0.37	0.40	0.34	0.26	0.34	0.25
Tiredness	-0.33	-0.35	-0.28	-0.22	-0.26	-0.20	-0.33	-0.18	-0.24	-0.22	-0.24	-0.32	-0.16	-0.03	0.01	0.12
Tension	-0.28	0.09	0.14	0.17	0.25	0.24	0.21	0.21	0.22	0.21	0.20	0.11	0.16	0.11	0.11	0.22
Calmness	-0.14	-0.30	-0.28	-0.38	-0.26	-0.36	-0.26	**-0.43**	-0.30	-0.36	-0.26	-0.24	-0.09	-0.18	-0.27	-0.21

Note. Significant (p< .05) correlations are bolded.

Table 4.8

Correlation Matrix Between Pre-Exercise Affect and Affective Recovery During MIIE

Pre-MIIE	IP-Energy	IP-Tired	IP-Tense	IP-Calm	P15-Energy	P15-Tired	P15-Tense	P15-Calm	P30-Energy	P30-Tired	P30-Tense	P30-Calm
Valence	**0.53**	-0.21	-0.19	-0.17	0.25	-0.11	**-0.50**	0.08	0.25	0.05	**0.46**	0.09
Energy	0.25	0.04	-0.03	0.04	**0.69**	0.17	**0.40**	0.27	**0.53**	-0.02	-0.01	-0.20
Tiredness	-0.33	0.30	-0.25	-0.16	0.28	**0.61**	**0.66**	0.26	-0.16	0.39	0.09	-0.12
Tension	0.15	-0.08	0.15	0.21	**0.62**	**0.51**	**0.82**	**0.56**	0.25	-0.05	0.37	-0.10
Calmness	0.13	**-0.49**	0.22	0.27	0.35	0.31	**0.53**	**0.84**	-0.19	-0.19	-0.07	**0.68**

Note. Significant (p< .05) correlations are bolded.

Discussion

The general aim of the present study was to explore the affective reactivity and recovery associated with high-intensity interval exercise (HIIE) when compared to moderate-intensity interval exercise (MIIE). In support of the first hypothesis, the HIIE condition resulted in more negative affective valence, along with greater activation and perceived stress, during the intervals. More specifically, these differences were first observed at the end of the second interval and continued throughout immediately-post recordings. Also, participants reported more Tension and less Calmness prior to and throughout recovery for the HIIE condition when compared to MIIE condition. However, contradictory to the first hypothesis, perceived Enjoyment did not differ between conditions. Participants also reported greater performance satisfaction following MIIE compared to HIIE, even though participants reported working relatively “harder” than usual for the HIIE. In testing the second hypothesis, these findings are supportive of HIIE resulting in greater declines in pleasantness from the beginning to end of each interval, but actually producing larger rebounds in recovery (increases in valence) following the rest-interval (end to beginning of succeeding intervals) when compared to MIIE. However, the recovery of pleasantness was not sufficient to meet the large, negative reactivity occurring during the exercise-interval, thus resulting in an overall less pleasant feeling state for the HIIE than induced by the MIIE. Lastly, pre-exercise affective states (i.e., valence and Energy) accounted for significant variance in HIIE and MIIE exercise-valence, but did not predict exercise enjoyment, satisfaction, or affective recovery.

The observed differences in core affect and emotional states between high- and moderate-intensity exercise are consistent with previous evidence. For example, an acute bout of high-intensity continuous exercise tends to result in a more negative (or less positive) affective response when compared to moderate- or light- intensity exercise (Ekkekakis, Parfitt, & Petruzzello, 2011; Ekkekakis & Petruzzello, 1999; Greene, Greenlee, & Petruzzello, 2018). It has also been suggested that these negative feelings from high-intensity exercise will rebound (i.e., become more positive) immediately following exercise cessation (Hall, Ekkekakis, & Petruzzello, 2002; Tate & Petruzzello, 1995), and may even elicit a more positive state than before exercise. The present findings are compatible with this prior evidence, as the high-intensity interval exercise (HIIE) did result in more negative (or less positive) affective states compared to the moderate-intensity interval exercise, and a large rebound was observed following the HIIE. Perhaps of greater interest was the affective reactivity and recovery that occurred within each exercise interval and between each subsequent interval, respectively.

In a scoping review of interval compared to continuous exercise, Stork and colleagues (2017) concluded that intervals produce similar or more negative affective responses than continuous exercise. However, this interpretation is questionable considering those findings were largely mixed, with several studies comparing not only exercise mode (interval versus continuous) differences, but also intensity differences (high-intensity / sprint intervals with moderate-intensity continuous). The present findings call into question the degree of negative reactivity that occurs during "high" intensity exercise. For example, while feeling states (i.e., affective valence) declined during each successive HIIE interval, this was accompanied by a moderate rebound (towards positive feeling states) between each consecutive interval. These rebounds potentially attenuate the plunge into unpleasant states. For the moderate-intensity interval, the reported declines in affective states during each bout were matched (or exceeded) by rebounds during the recovery periods. This resulted in a more positive feeling state overall. Although the present study did not compare interval to continuous exercise, the relative intensities (via

$\%HR_{peak}$ and $\%VO_{2peak}$) reached within the HIIE and MIIE were reflective of vigorous-to-maximal intensity and moderate-to-vigorous intensity, respectively, as set forth by the American College of Sports Medicine (ACSM, 2018). The MIIE condition, although reaching a vigorous intensity as early as the second interval, resulted in improvements in feeling states during (at the beginning) the exercise intervals, with “negative reactivity” never declining below pre-exercise states. Furthermore, the HIIE condition, reflective of vigorous-to-maximal intensity, did result in large affective declines. However, the average valence never moved into an “unpleasant” state, suggesting the 1-min rest intervals provided some time for affective rebound which seems to have slowed (or stalled) the affective decline.

4.3 Cardiac Vagal Tone Oscillations

Purpose & Hypotheses

Evidence suggests a relationship between heart rate variability (HRV) and affective states, where emotional disorders (e.g., Depression, Anxiety) are related to suppressed vagal tone. This results in deficient, as opposed to appropriate and healthy, stressor reactivity (Bernston & Cacioppo, 2003; Chalmers, Quintana, Abbott, & Kemp, 2014; Kemp et al., 2010; Thayer et al., 2012). In the exercise-domain, it has been shown that greater parasympathetic (vagal) tone prior to initiating exercise will result in more optimized performance (Föhr et al., 2017; Sandercock, Bromley, & Brodie, 2005). However, there is a lack of understanding regarding how tonic (resting) vagal tone is associated with affective reactivity to exercise. It is likely that differences in the physical stress-stimulus (e.g., high- versus moderate-intensity exercise) will alter the extent of vagal tone withdrawal and parasympathetic recovery, which may be predictive of how someone feels (e.g., valence, perceived stress) during exercise. Thus, the purpose of the present study was to explore the potential role of tonic (i.e., resting) HRV as a predictor of affective reactivity and recovery, and to determine the extent to which high- and moderate-intensity interval exercise influences phasic (reactivity) vagal tone and parasympathetic recovery. It was hypothesized that: 1) tonic cardiac vagal tone would significantly predict affective responses and perceived stress during both the high-intensity interval (HIIE) and moderate-intensity interval (MIIE) exercise bouts; and 2) the HIIE would induce greater vagal tone withdrawal during exercise, and result in delayed vagal tone through recovery, which would be associated with affective responses.

Data Analysis

Pre- and post-exercise indices of HRV were recorded as an average over a 5-minute period, while the rest-intervals that occurred "during" exercise were limited to an average of 1-minute recordings. All data were analyzed using a "very low threshold" within Kubios HRV analysis software (Kubios HRV Premium version. 3.3.0, 2019). Data were excluded if artifact within the time of interest was above 3%. A small number of participants (n=4) were excluded from regression analyses due to data artifact for tonic (baseline) vagal tone (reducing sample size to 21). A total of 16 participants were excluded from Condition x Time comparisons due to large data artifact (reducing sample size to 9). From artifact-free data, average heart rate (HR), Root Mean Square of the Successive Differences (RMSSD) and log-transformed High Frequency (HF) power were derived.

Statistical Analysis

Pearson's correlations were used to explore relationships among vagal tone with affective responses and perceived stress. In the presence of meaningful correlations, separate hierarchical regressions [Block 1 = Age, Sex, BMI, and VO_{2peak}, Block 2 = Pre-exercise valence, Block 3= Pre-exercise RMSSD / HF-Power] were conducted to explore the variance explained by Heart

Rate Variability (HRV) on affective reactivity and recovery during MIIE and HIIE. To test the second hypothesis, Separate 2 (Condition) x 7 (Time) repeated measures of Analysis of Variance (RMANOVA) were conducted to determine differences in vagal tone between the MIIE and HIIE conditions prior to (PRE), during each rest-interval, immediately post (IP), and 15-minutes post exercise. Cohen's *d* (d= 0.2, 0.5, 0.8 are considered small, moderate, and large effects, respectively; Cohen, 1988) values are reported in order to provide the magnitude of difference at each time point for each relative intensity variable. All analyses were completed using SPSS (SPSS for Windows, version 24.0), and alpha was set to .05 to denote significance.

Results

Separate RMANOVAs revealed no significant differences between baseline, pre-HIIE, and pre-MIIE average heart rate (HR; $F(1.6, 33.71)= .579$, $p= .487$, $\eta_p^2= .034$), RMSSD ($F(1.5, 21.31)= 1.49$, $p= .246$, $\eta_p^2= .096$), or HF-power ($F(2, 28)= .783$, $p= .467$, $\eta_p^2= .053$). This suggests tonic (i.e., resting) vagal tone was similar across condition days, permitting further phasic (reactivity) and recovery vagal tone to be analyzed (see Table 4.9). However, a significant sex difference ($p= .017$, $\eta_p^2= .242$, $d= 1.111$) was observed in HF-power, where females (7.54±0.73) had greater vagal tone than males (6.41±1.28).

Table 4.9

Tonic HR and Vagal Tone Comparisons between Condition Days (*M*±*SD*)

	Baseline	Pre-HIIE	Pre-MIIE
HR *(beats/min)*	67.63±12.33	70.31±13.61	69.11±14.20
RMSSD *(ms)*	83.38±46.79	74.85±44.63	63.11±36.98
HF-power *(log)*	7.10±1.26	6.87±2.08	6.74±1.78

Note. Values are reflective of a 5-min tonic (i.e., resting) recording within each respective condition. RMSSD and log-transformed HF-Power reflect Vagal Tone using the Time and Frequency Domains, respectively.

Significant Condition x Time interactions were observed for average HR ($F(6, 48)= 6.47$, $p< .001$, $\eta_p^2= .447$) and HF-power ($F(6, 48)= 3.67$, $p= .004$, $\eta_p^2= .314$), where the HIIE resulted in a faster HR and greater vagal tone withdrawal (less HF-power) at all rest-intervals during the exercise protocol, but returned to similar values during recovery (15-minutes post-exercise). A Condition x Time interaction was not observed for RMSSD ($F(6, 48)= .937$, $p= .478$, $\eta_p^2= .105$), although a Time main effect was observed. Both the HIIE and MIIE resulted in large vagal withdrawal (declines in RMSSD) from pre- to the first rest-interval. Slight declines in vagal tone were observed across subsequent rest-intervals during the exercise protocol, with large rebounds of vagal tone during recovery (see Figure 4.8). Variable scores by condition and time with effect sizes can be viewed in Table 4.10.

Table 4.10

Magnitude of Effect in HR, HF-power, and RMSSD Between Conditions across Time

		Pre-	**Rest-1**	**Rest-2**	**Rest-3**	**Rest-4**	**IP**	**Post-15**
HR ($b \cdot min^{-1}$)	**HIIE**	68.3±13.4	145.7±14.6	155.1±15.8	158.1±15.7	159.4±15.0	158.9±13.1	95.8±19.0
	MIIE	68.6±14.6	127.2±13.7	134.3±13.5	138.5±15.3	141.2±16.9	145.6±15.2	86.1±13.4
	d	*-.02*	***1.4***	***1.5***	***1.3***	***1.2***	***.99***	***.63***
HF-power (*log*)	**HIIE**	6.5±1.6	1.6±1.7	1.2±1.5	0.8±1.5	1.3±1.5	2.2±2.8	4.1±2.9
	MIIE	6.9±1.3	3.7±2.4	3.0±1.7	2.1±1.8	2.0±1.4	1.3±1.4	5.4±2.5
	d	*-.29*	***-1.1***	***-1.2***	***-.83***	***-.51***	***.43***	***-.51***
RMSSD (*ms*)	**HIIE**	59.2±30.1	11.1±10.2	7.7±6.9	5.9±4.1	8.6±6.9	22.2±28.0	38.9±41.0
	MIIE	63.1±41.8	15.4±14.1	11.7±6.8	7.7±3.8	6.3±2.5	6.3±3.2	49.3±60.6
	d	*-.11*	*-.37*	***-.62***	***-.48***	***.47***	***.85***	*-.21*

Note. Significant differences ($p < .05$) are noted by a bolded effect size (Cohen's *d*).

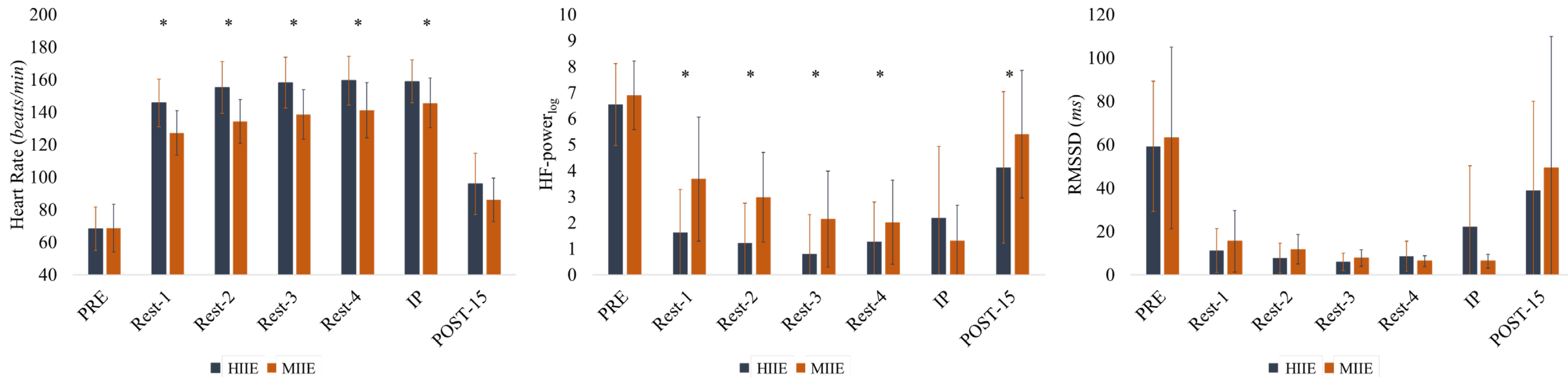

Figure 4.8 Differences in HR and vagal tone between conditions across time. (***Note***. Indicates significant difference (p< .05) between conditions. Magnitude of effects (Cohen's *d*) and raw data can be observed in Table 4.3.2).

In exploring psychophysiological relationships, significant ($p_s < .05$) correlations were observed between Baseline, resting vagal tone and various affective state measures. More specifically, Baseline RMSSD was moderately correlated with Baseline perceived physiological activation ($r = .403$), and Baseline HF-power had small-to-moderate correlations with Baseline Energy ($r = .530$), perceived physiological activation ($r = .409$), Tension ($r = .313$), valence ($r = .280$), Tiredness ($r = -.375$), Stress symptoms ($r = -.386$), and Depression symptoms ($r = -.410$).

Similar relationships were also observed between pre-HIIE HR and vagal tone with pre-HIIE affective states, where pre-HR was low-to-moderately correlated with pre-valence ($r = -.380$), perceived activation ($r = .425$), perceived stress ($r = .392$), and Tension ($r = .387$), and pre-HF-power had a small correlation with pre-valence ($r = .240$); pre-HIIE RMSSD was not correlated with affective states. Lastly, similar relationships were observed for pre-MIIE HR and vagal tone with pre-MIIE affective states. Pre-MIIE HR had small-to-moderate correlations with pre-valence ($r = -.415$), Energy ($r = -.325$), Tiredness ($r = .496$), while small-to-moderate relationships were observed between pre-RMSSD and HF-power with pre-valence ($r = .561$ and .439, respectively), Energy ($r = .239$ and .337, respectively), and Tiredness ($r = -.464$ and -.539, respectively).

Although several small-to-moderately high correlations were observed between pre-exercise tonic vagal tone (i.e., RMSSD and HF-power) and exercise-affect (see Table 4.11 & 4.12), vagal tone was not predictive of affective reactivity or recovery during either condition at any time-point ($p_s > .05$). A trend was observed between conditions where pre-exercise HF-power was positively related to valence (i.e., greater vagal tone related to more positive feeling states) through the exercise-intervals up to 5-minutes post-exercise, with the exception of a weakened relationship during the final (fifth) HIIE interval

Table 4.11

Relationships Between Tonic Vagal Tone and Valence Reactivity

		1A	***1B***	***2A***	***2B***	***3A***	***3B***	***4A***	***4B***	***5A***	***5B***
	HR (*b·min*$^{-1}$)	***-0.36***	**0.47**	**-0.49**	**-0.54**	**-0.60**	**-0.56**	**-0.57**	**-0.56**	**-0.51**	**-0.52**
MIIE	***RMSSD*** (*ms*)	0.29	0.24	0.29	0.29	***0.38***	***0.30***	***0.33***	0.29	0.25	0.24
	HF-power (*log*)	***0.39***	***0.42***	***0.43***	**0.45**	**0.49**	**0.49**	***0.44***	**0.47**	***0.38***	***0.42***
	HR (*b·min*$^{-1}$)	***-0.30***	-0.27	***-0.39***	***-0.35***	**-0.47**	**-0.48**	**-0.47**	***-0.38***	**-0.50**	-0.25
HIIE	***RMSSD*** (*ms*)	0.29	0.18	***0.33***	0.17	0.22	0.25	0.21	0.10	***0.31***	0.10
	HF-power (*log*)	**0.47**	***0.36***	**0.55**	***0.37***	***0.33***	***0.31***	0.28	0.18	0.27	0.24

Note. Significant (*p*< .05) relationships are bolded.

Table 4.12

Relationships Between Tonic Vagal Tone and Affective Recovery

		IP	***P5***	***P15***	***P20***	***P25***	***P30***	***Enjoyment***
	HR (*b·min*$^{-1}$)	**-0.50**	**-0.59**	***-0.34***	-0.14	-0.20	-0.21	**-0.46**
MIIE	***RMSSD*** (*ms*)	0.26	**0.48**	**0.51**	***0.30***	0.30	***0.32***	**0.57**
	HF-power (*log*)	***0.37***	**0.50**	***0.32***	0.20	0.21	0.26	***0.42***
	HR (*b·min*$^{-1}$)	**-0.61**	***-0.39***	0.01	0.17	0.08	0.09	***-0.31***
HIIE	***RMSSD*** (*ms*)	***0.38***	0.25	-0.11	***-0.36***	***-0.39***	***-0.35***	0.11
	HF-power (*log*)	***0.34***	***0.42***	-0.16	-0.27	-0.20	-0.12	0.17

Note. Significant (*p*< .05) relationships are bolded.

To determine the associations between perceptions and physiological (via vagal tone withdrawal) stress, time-lagged correlations revealed significant ($p_s < .05$) relationships among perceived stress during the exercise-intervals and the recorded HF-power during subsequent rest-intervals during HIIE (see Figure 4.9). More specifically, while HF-power was not related to perceived stress prior to the HIIE, perceived stress at the end of each exercise-interval was moderately correlated with HF-power recorded in the succeeding rest-interval. Further, the preceding HF-power was associated with perceived stress at the beginning of the subsequent interval. Additionally, a trend was observed where strength of relationships declined with successive intervals, to the point where the final rest-interval (preceding the final exercise-interval) was not related to perceived stress during. No meaningful relationships were observed between vagal tone and perceived stress during MIIE.

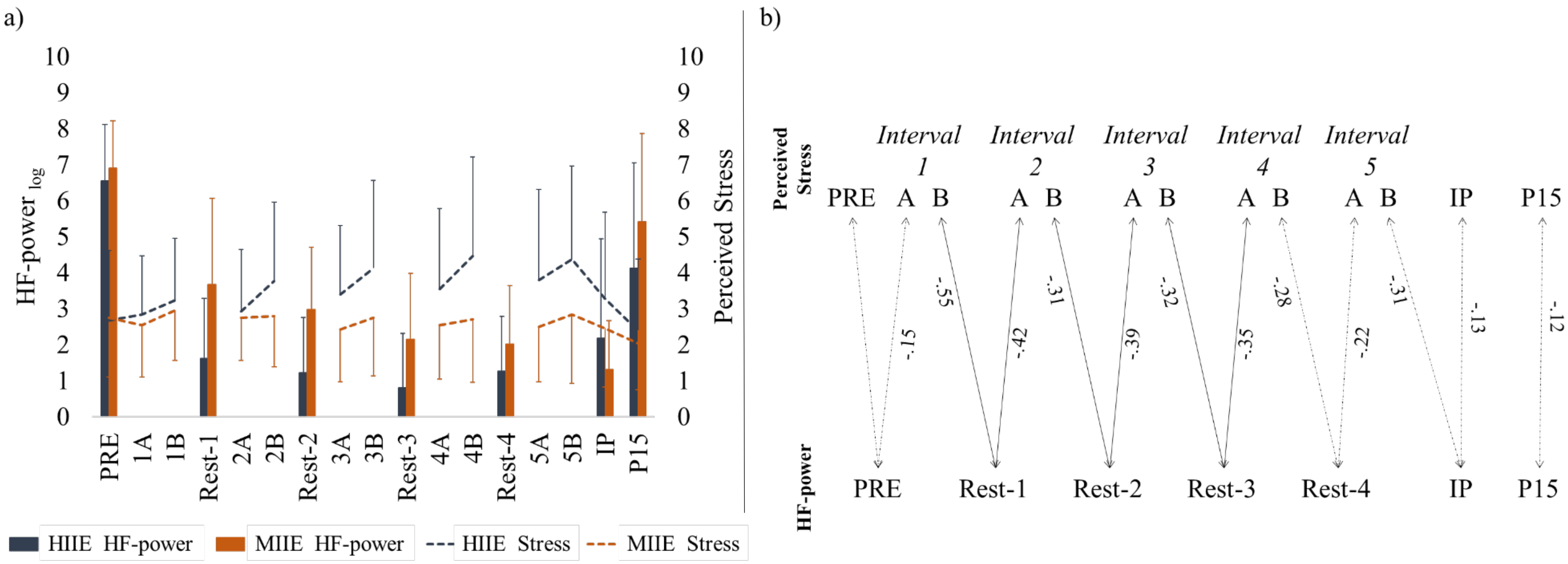

Figure 4.9 Psychophysiological reactivity via HF-power and perceived stress (a) and the time-lagged association during the HIIE (b). (***Note***. Significant ($p < .05$) relationships are denoted by a solid line, while dashed lines were considered non-significant).

Discussion

It is generally agreed upon that greater tonic (resting) variability in heart beats is associated with better overall health (e.g., less stress, greater indices of life quality) and a likelihood to respond more optimally to a stressor (e.g., emotional, social, physical). While vagal tone (i.e., parasympathetic tone) has been commonly examined, along with perceptions of stress and mortality risk (Thayer et al., 2012), less is understood regarding how resting vagal tone (a) is associated with how one feels in that moment (i.e., state-dependent association) or (b) may predict affect (i.e., affective reactivity) during a physically stressful task. The primary aims presented here were to explore the potential role of tonic (i.e., resting) HRV as a predictor of affective reactivity and recovery during a bout of MIIE and HIIE (physical stressors), and to determine the extent to which this exercise influences phasic (reactivity) vagal tone and parasympathetic recovery. In testing the first hypothesis, meaningful relationships between vagal tone, predominantly in HF-power, and affective reactivity (during the exercise-intervals) and recovery were observed for both conditions. However, when adding vagal tone (i.e., RMSSD, HF-power) to a regression model, vagal tone did not explain any additional unique variance to the variance already accounted for by age, sex, BMI, cardiorespiratory fitness (VO_{2peak}), pre-exercise valence, and Energy. In addition, the present findings suggest state-dependent associations between tonic vagal tone and affective states, where greater vagal tone was associated with more positive feeling states. In support of the second hypothesis, both exercise conditions resulted in significant vagal tone withdrawal (depicted via HF-power), with HIIE resulting in greater vagal tone withdrawal at each interval when compared to MIIE.

Additionally, vagal tone did not fully recover for either condition within the 15-minutes post-exercise. HIIE resulted in greater vagal tone withdrawal when compared to MIIE, which supports the hypothesis that HIIE would result in a greater delay of vagal recovery. Lastly, in exploring the relationships between vagal tone and perceived stress, these findings suggest that as perceived stress increases, vagal tone declines (or withdraws), but only in the presence of a sufficient stimulus that induces perceived stress. This latter finding should be viewed somewhat cautiously given the relatively small number of participants on which these analyses were done.

4.4 Role of Individual Differences

Purpose

Individual trait differences, such as one's innate tendency to be more extraverted, conscientious, emotionally stable, or to prefer and tolerate higher-intensity exercise, have been suggested to be associated with an individual's likelihood to engage in exercise. Evidence even suggests that these personality traits can predict how frequently and how long someone chooses to exercise, along with which exercise mode one most commonly performs (Allen & Laborde, 2014; Box et al., 2019; Courneya & Hellsten, 1998; Rhodes & Smith, 2006). Along with personality, individuals regulate their behavior differently, such that some individuals are innately driven from within (i.e., an internal locus of control) while others need some form of reward or 'punishment' avoidance (i.e., an external locus of control) to drive behavior. With personality and regulation-style as more enduring, cross-situational characteristics, it seems imperative to consider how these individual differences influence not only behavior, but also personal reactivity to an event (e.g., high-intensity exercise), which may lead to engagement (or disengagement) of future behavior (e.g., high-intensity exercise programming). Thus, the purpose of the present study was to determine the role(s) of individual differences on psychophysiological reactivity and recovery to an acute bout of high-intensity interval exercise. It was hypothesized that: 1) greater levels of trait Neuroticism would be related to more Anxiety, Depression, and Stress symptoms; (2) Extraversion and Conscientious traits would be positively related with exercise-intensity preference and tolerance; 3) Neuroticism, Anxiety, Depression, and Stress symptoms would be inversely related to baseline cardiac vagal tone and affective states; and 4) greater trait indices of Extraversion, Conscientiousness, Emotional Stability, higher-intensity Preference and Tolerance would be associated with more positive feeling states during and following high-intensity interval exercise.

Statistical Analysis

To determine whether sex differences were present, a Multivariate Analysis of Variance (MANOVA) was conducted on all dependent variables. Pearson's correlations were used to explore relationships among trait variables, emotional disorder symptoms, and affective responses and perceived stress. Associations among individual difference variables, along with associated construct reliability can be viewed in Table 4.13. In the presence of meaningful correlations between trait variables and exercise-affect, separate hierarchical regressions [Block 1 = Age, Sex, BMI, and VO_{2peak}, Block 2 = Pre-exercise valence, Block 3= trait variable of interest] were conducted to explore the unique variance explained by trait differences on affective reactivity and recovery during moderate- and high-intensity interval exercise. All analyses were completed using SPSS (SPPS for Windows, version 24.0), and alpha was set to .05 to denote significance.

Table 4.13

Individual Difference Variables Construct Reliability and Inter-correlations

	α	1	2	3	4	5	6	7	8	9	10	11
1. Intensity-Preference	.800	1	0.26	-0.17	-0.16	-0.02	-0.16	-0.05	0.03	0.35	-0.24	0.15
2. Intensity-Tolerance	.858		1	**0.52**	-0.24	0.08	0.34	0.40	0.36	0.19	0.16	-0.04
3. Autonomy	-			1	-0.01	-0.30	0.36	**0.53**	**0.43**	-0.24	-0.16	**-0.42**
4. Extraversion	.902				1	-0.11	0.28	0.19	0.16	**-0.55**	-0.15	**-0.44**
5. Neuroticism	.894					1	-0.01	-0.22	-0.19	0.33	**.73**	**0.74**
6. Agreeableness	.805						1	0.33	0.28	-0.28	-0.06	**-0.42**
7. Conscientious	.809							1	**0.48**	-0.36	-0.01	-0.40
8. Openness	.852								1	0.08	-0.16	-0.30
9. Depression	.597									1	0.35	**0.65**
10. Anxiety	.786										1	**0.67**
11. Stress	.805											1

Note. Significant ($p < .05$) inter-correlations are bolded. Variable construct reliability is provided (Cronbach's alpha (α)), except for Autonomy, which is assessed via a single item.

Results

A MANOVA revealed significant sex differences for Conscientiousness (p= .013, η_p^2= .260) and Depression (p= .048, η_p^2= .173). Individual difference variables can be viewed in Table 4.14.

Table 4.14 Participant Trait Characteristics (*M*±*SD*)

	Males (*n*=11)	Females (*n*=13)	Total (*N*=24)
BMI	26.10±4.85	25.65±3.65	25.86±4.15
Age (*years*)	24.55±5.13	22.38±2.81	23.38±4.09
Biological Disposition			
HF-power*	6.41±1.28	7.54±0.73	7.01±1.15
Personality			
Intensity-Preference	32.64±5.12	29.00±4.58	30.67±5.08
Intensity- Tolerance	29.09±4.78	27.92±6.40	28.46±5.63
Extraversion	3.19±1.01	3.88±0.82	3.56±0.95
Neuroticism	2.38±1.02	2.65±0.93	2.53±0.96
Conscientiousness*	3.58±0.53	4.15±0.61	3.88±0.63
Openness	3.75±0.78	3.71±0.50	3.73±0.63
Agreeableness	4.06±0.53	4.26±0.60	4.17±0.57
Regulation-style			
RAI	13.82±5.49	15.13±6.50	14.53±5.96
Amotivation	1.07±0.23	1.10±0.28	1.08±0.25
Extrinsic	1.57±0.74	2.00±0.84	1.80±0.81
Introjected	3.89±0.90	3.85±1.03	3.86±0.95
Identified	4.27±0.61	4.52±0.58	4.41±0.59
Integrated	3.61±1.24	4.33±1.01	4.00±1.15
Intrinsic	4.18±0.70	4.37±0.85	4.28±0.77
Affective Disorder			
Depression*	5.00±2.68	2.85±1.99	3.83±2.53
Anxiety	6.18±4.26	8.54±2.63	7.46±3.60
Stress	14.09±6.86	12.15±5.21	13.04±5.97

Note. *Significant difference (p< .05) by sex. Relative Autonomy Index (RAI) is a single item score reflective of individual's autonomy. One participant did not complete all aspects of the individual difference measures and was removed from the following analysis.

Pearson's correlations revealed meaningful relationships between individual difference variables and psychophysiological measures (see Table 4.15). In particular, greater levels of Extraversion and Conscientiousness were related to more positive feeling states (i.e., more positive valence, more Energy, less Tiredness), with Conscientiousness also strongly correlated with tonic vagal tone. In addition, greater indices of Depression and Stress were inversely related to feeling states (i.e., more negative valence, less Energy, more Tiredness), and both Depression and Stress had a moderate, inverse relationship with tonic vagal tone.

Table 4.15

Relationships Among Individual Differences with Baseline Affect and Vagal Tone

	Valence	Activation	Perceived Stress	Energy	Tired	Tense	Calm	HF-power
Intensity-Preference	-0.37	**-0.48**	-0.01	-0.184	**0.44**	-0.08	0.21	-0.35
Intensity-Tolerance	-0.13	-0.09	0.11	-0.02	0.09	0.09	0.22	0.32
Autonomy	0.03	-0.06	-0.07	0.09	-0.32	-0.04	0.34	**0.47**
Extraversion	**0.52**	0.35	-0.26	**0.54**	-0.25	0.23	-0.31	0.05
Neuroticism	-0.01	0.17	0.19	-0.19	**0.48**	0.04	-0.07	-0.19
Agreeable	0.27	0.13	0.11	0.17	0.01	0.16	0.02	0.23
Conscientious	**0.44**	0.06	-0.24	0.33	-0.36	-0.10	0.21	**0.62**
Openness	0.14	0.09	-0.14	0.30	-0.04	0.38	0.22	0.31
Depression	**-0.52**	-0.35	0.05	**-0.52**	**0.49**	-0.02	0.28	-0.41
Anxiety	0.03	0.18	0.34	-0.08	0.27	0.05	-0.15	0.12
Stress	**-0.43**	-0.11	0.24	**-0.45**	**0.65**	-0.17	0.01	-0.39

Note. Significant ($p < .05$) relationships are bolded.

Several meaningful relationships emerged between individual difference variables and affective valence reactivity and recovery to the HIIE and MIIE conditions (see Figure 4.10). For HIIE, indices of Neuroticism (r_s= -.27 to -.48), Depression (r_s= -.39 to -.66), Anxiety (r_s= -.23 to -.61), and Stress (r_s= -.38 to -.62) were consistently and negatively associated with affective valence during the exercise-intervals. In addition, levels of Extraversion (r_s= .25 to .36) and Conscientiousness (r_s= .22 to .52) were positively associated with valence during the exercise-intervals, but these relationships ceased by the end of the fourth exercise-interval. However, Extraversion was mainly associated (r_s= .30 to .37) with more positive valence during recovery. For MIIE, indices of Intensity-tolerance (r_s= .27 to .46), Conscientiousness (r_s= .61 to .75), and Autonomy (r_s= .32 to .50) were positively associated with affective valence (i.e., more pleasant) during the exercise-intervals, while Depression (r_s= -.31 to -.60) and Stress (r_s= -.43 to -.56) were associated with less pleasant valence during the exercise-intervals. During recovery, Extraversion (r_s= .32 to .37) was positively related to affective valence, similarly to HIIE.

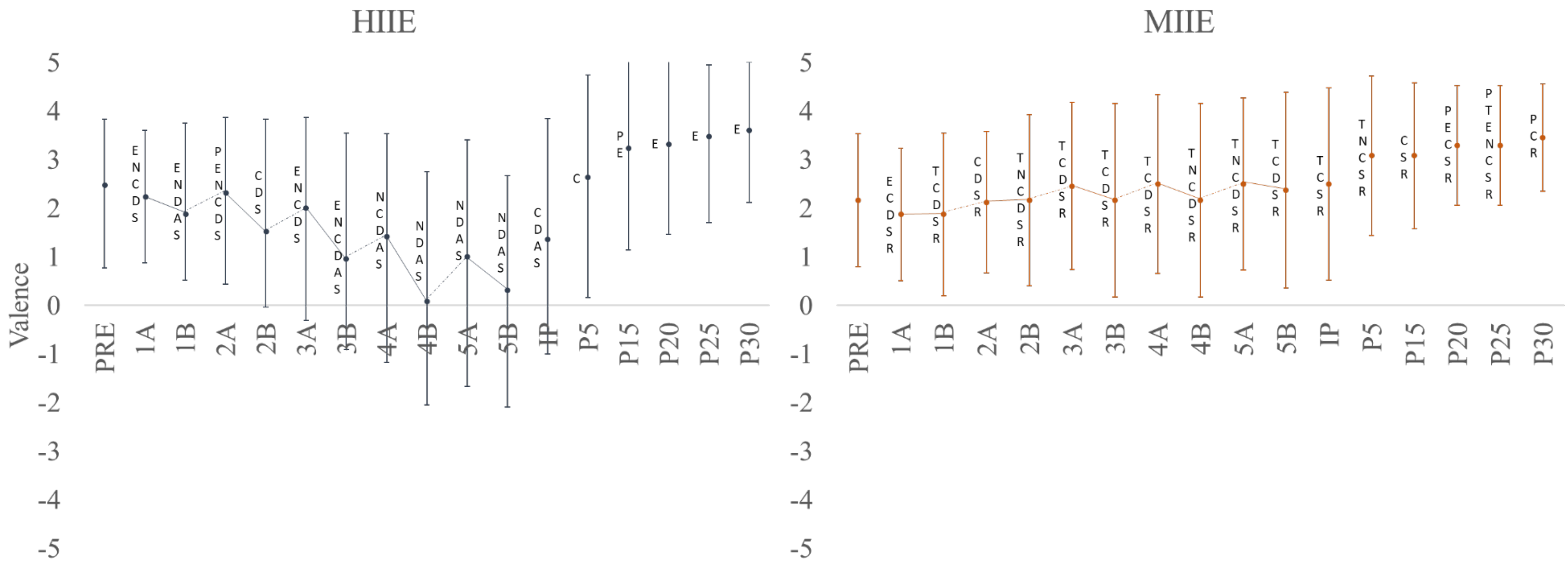

Figure 4.10 Relationships between individual differences and condition valence. (***Note***. Significant (p< .05), meaningful (r > .3) relationships are denoted here as Intensity-Preference (P), Intensity-Tolerance (T), Extraversion (E), Neuroticism (N), Conscientiousness (C), Depression (D), Anxiety (A), Stress (S), and Relative Autonomy Index (R) at respective time-points).

For perceived activation, only intensity-Preference scores were significantly ($p_s < .05$) associated during HIIE and MIIE for the exercise-intervals ($r_s = -.33$ to $-.57$ and $-.36$ to $-.59$, respectively) and during recovery ($r_s = -.39$ to $-.49$ and $-.37$ to $-.47$, respectively), where higher intensity-Preference was related to less perceived activation during and following the exercise conditions.

Significant ($p_s < .05$), positive relationships emerged in both HIIE and MIIE between Neuroticism ($r_s = .32$ to $.48$ and $.25$ to $.45$, respectively) and Anxiety ($r_s = .48$ to $.59$ and $.36$ to $.50$, respectively) with perceived Stress during the exercise-intervals. Anxiety was also associated with greater perceived stress during recovery ($r_s = .29$ to $.45$ and $.32$ to $.43$, respectively) of HIIE and MIIE.

Discussion

Most people respond more negatively to high-intensity exercise, but some individuals choose to continue to engage in high-intensity programming. Emerging evidence suggests that individual differences may be mediating the affective decline (i.e., decreasing pleasantness, increasing unpleasantness) typically seen during high-intensity exercise. The aim of this study was to explore associations between individual differences, such as personality and regulation-style, with baseline psychophysiological variables (e.g., tonic vagal tone, emotional disorders, affective states) and affective reactivity to an acute bout of high-intensity and moderate-intensity interval exercise. The findings support the proposed hypotheses in that greater reports of Neuroticism were related to more Anxiety and Stress symptoms, but not Depression. In addition, Extraversion was inversely related to Depression and Stress symptoms; however, Extraversion and Conscientious were not related to exercise-intensity Preference or Tolerance, nor any other trait variable. In testing the second hypothesis, cardiac vagal tone and affective states were inversely related to Depression and Stress Symptoms, while Conscientiousness was positively associated with baseline cardiac vagal tone and affective states. In addition, Extraversion was associated with more positive baseline feeling states. Lastly, affective (i.e., valence) reactivity and recovery was associated with numerous individual difference variables. However, common themes observed were for greater Neuroticism, Depression, Anxiety, and Stress leading to more negative feeling states during the high-intensity interval condition, with higher-intensity Tolerance and Conscientiousness providing additional associations with positive valence during the moderate-intensity interval condition.

4.5 Exercise-Affect Reactivity Model

Purpose

Individuals may have innate tendencies (e.g., personality traits, motivations, behavior-regulation styles) to respond to a stressor (e.g., high-intensity exercise) in a particular way (e.g., change in feeling states). These responses may be compromised (e.g., decreasing pleasantness, increasing unpleasantness) or optimized (e.g., increasing pleasantness, decreasing unpleasantness) given consideration of other existing variables (e.g., emotional disorder, prior exercise experience, fitness levels, pre-stimulus stress-load). Thus, the purpose of the present study was to propose a high-intensity exercise-affect reactivity model (see Figure 4.11) that considers biological dispositions, trait differences, and pre-exercise affective states as predictors and potential mediators. First, associations between biological dispositions, trait tendencies, and other individual characteristics (i.e., age, sex, BMI, cardiorespiratory fitness, exercise behavior) were explored. Second, how these variables interact to predict variance in affective reactivity to an acute bout of high-intensity interval exercise are presented.

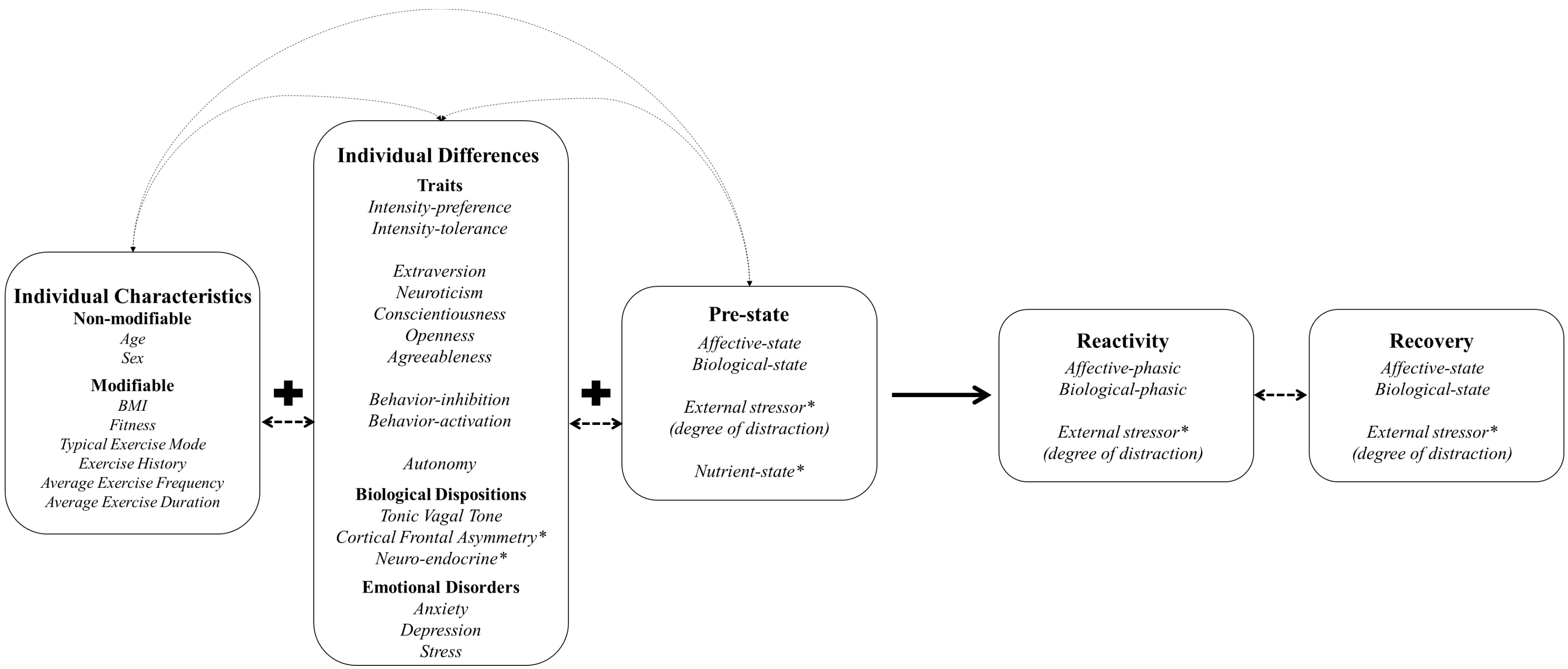

Figure 4.11 Hypothesized Exercise-Affect Reactivity Model. (***Note***. *indicates variables that were not assessed within the present study).

Statistical Analysis

Pearson's correlations were used to explore relationships among individual characteristics, individual differences, pre-exercise states, and affective and cardiac vagal tone reactivity and recovery. Separate hierarchical regressions [Block 1 = Individual Characteristics, Block 2 = Individual Differences, Block 3= Pre-exercise states] were conducted to explore the variance explained on affective and cardiovascular reactivity during each interval (5, separate hierarchical regressions) and through recovery during moderate- and high- intensity interval exercise. Of note, these regressions were critically under-powered. Thus, variance explained will be expressed by an adjusted R^2. All analyses were completed using SPSS 24.0.0.0, and alpha was set to .05 to denote significance.

Results

Inter-relationships among Individual Difference Variables

In exploring relationships among individual characteristic variables (see Table 4.16), males (r= -.52, p< .05) and those with a lower BMI score (r= -.47, p< .05) had greater VO_{2peak} values. In addition, as exercise frequency (days·wk^{-1}) increased, exercise duration increased (r= .52, p< .05). For individual difference variables, inter-relationships were observed (see Table 4.17), where behavioral-inhibition (i.e., tendency to withdrawal) was strongly, positively related to Neuroticism (r= .73, p< .05), Anxiety symptoms (r= .64, p< .05), and Stress (r= .54, p< .05), while Agreeableness (r= .53, p< .05) and Conscientiousness (r= .54, p< .05) were positively related to Autonomy (i.e., sense of self-control). Depression symptoms were inversely related to Extraversion (r= -.55, p< .05), Conscientiousness (r= -.36, p< .05), and Vagal Tone (r= -.41, p< .05), suggesting greater Depression symptoms were associated with reduced parasympathetic activity. Stress was related to all Big Five factors (Extraversion, Conscientiousness, Neuroticism, Agreeableness, & Openness), Autonomy, and Depression and Anxiety Symptoms. Pre-exercise affective valence was positively related to pre-exercise Energy (r_s= .32 to .48) and pre-exercise Vagal Tone (r_s= .44 to .58) and inversely related to pre-exercise Tiredness (r_s= -.32 to -.58) for both conditions (see Table 4.18). In addition, several other individual difference variables were related to each other (see Table 4.19) and with pre-exercise affective and biological states (see Table 4.20). More specifically, common associations were observed where pre-exercise valence was positively associated with Conscientiousness (r_s= .62 to .63), pre-exercise Tiredness was positively associated with Stress (r_s= .35 to .42) and inversely related to Conscientiousness (r_s= -.35 to -.42), pre-exercise Calmness was inversely associated with Extraversion (r_s= -.34 to -.43) and positively related to Depression (r_s= .35 to .37). Lastly, pre-exercise Vagal Tone (via HF-power) was positively associated with greater reported exercise frequency (r_s= .39 to .45), duration (r_s= .32 to .33), Behavioral-activation (r_s= .32 to .56), and Conscientiousness (r_s= .59 to .61), while inversely related to Depression (r_s= -.42 to -.45).

Table 4.16

Relationships among Individual Characteristic Variables

	(*M*±*SD*)	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Age	23.3±4.0	1.00	-0.25	0.32	0.13	-0.10	0.08	**0.51**
2. Sex	-		1.00	-0.02	**-0.52**	0.07	-0.04	0.14
3. BMI	25.7±4.1			1.00	**-0.47**	-0.10	-0.24	0.27
4. VO_{2peak}	41.6±9.4				1.00	0.23	0.17	0.11
5. Exercise Frequency	4.0±1.3					1.00	**0.52**	0.13
6. Exercise Duration	55.8±23.8						1.00	0.05
7. Exercise Participation Length	-							1.00

Note. Significant ($p < .05$) relationships are bolded.

Table 4.17

Relationships among Trait Variables

	(*M*±*SD*)	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Intensity-preference	30.7±5.1	0.26	-0.19	-0.17	-0.16	-0.02	-0.16	-0.05	0.03	-0.35	0.35	-0.24	0.15
2. Intensity-tolerance	28.5±5.6	1.0	-0.09	**0.52**	-0.24	0.08	0.34	0.40	0.36	0.32	0.19	0.16	-0.04
3. Behavior-inhibition	19.4±3.9		1.0	-0.01	-0.03	**0.73**	0.07	0.04	-0.27	0.04	-0.09	**0.64**	**0.54**
4. Autonomy	14.5±6.0			1.0	-0.01	-0.30	0.36	**0.53**	**0.43**	**0.47**	-0.24	-0.16	**-0.42**
5. Extraversion	3.5±0.9				1.0	-0.11	0.28	0.18	0.16	0.05	**-0.55**	-0.15	**-0.44**
6. Neuroticism	2.5±0.9					1.0	-0.01	-0.21	-0.19	-0.19	0.33	**0.73**	**0.74**
7. Agreeableness	4.1±0.6						1.0	0.33	0.28	0.23	-0.28	-0.06	**-0.42**
8. Conscientious	3.9±0.6							1.0	**0.48**	**0.62**	**-0.36**	-0.01	**-0.40**
9. Openness	3.7±0.6								1.0	0.31	0.08	-0.16	-0.30
10. Vagal Tone	7.0±1.1									1.0	**-0.41**	0.12	**-0.39**
11. Depression	3.8±2.5										1.0	0.35	**0.65**
12. Anxiety	7.5±3.6											1.0	**0.67**
13. Stress	13.0±6.0												1.0

Note. Significant (*p*< .05) relationships are bolded.

Table 4.18

Relationships among Pre-Exercise Affective States

		M±*SD*	2	3	4	5	6	7	8	9	10	11	12
HIIE	1. Valence	2.5±1.4	**0.48**	**-0.58**	-0.19	0.07						**0.58**	
	2. Energy	10.2±2.6	1.0	**-0.59**	0.24	-0.32						0.19	
	3. Tiredness	11.2±3.5		1.0	-0.21	0.24						-0.28	
	4. Tension	6.3±1.9			1.0	**-0.53**						-0.09	
	5. Calmness	15.0±3.3				1.0						-0.12	
MIIE	6. Valence	2.2±1.4					1.0	0.32	-0.32	-0.10	0.08		**0.44**
	7. Energy	8.9±3.3						1.0	0.02	**0.53**	0.13		**0.34**
	8. Tiredness	12.6±4.2							1.0	**0.57**	**0.38**		**-0.54**
	9. Tension	5.3±1.3								1.0	**0.59**		-0.03
	10. Calmness	15.7±4.4									1.0		0.06
	11. HIIE-Vagal Tone	7.0±1.8										1.0	
	12. MIIE-Vagal Tone	6.7±1.6											1.0

Note. Significant ($p < .05$) relationships are bolded.

Table 4.19

Relationships between Individual Characteristics and Trait Variables

	Pref	Tol	BIS	Drive	Fun seek	Reward	RAI	E	N	A	C	O	Vagal Tone	Depression	Anxiety	Stress
BMI	**.60**	-0.01	0.05	0.18	0.16	0.15	-0.28	0.10	0.20	0.08	-0.12	0.14	-0.32	0.15	-0.04	0.25
Sex	**-0.36**	-0.11	**0.37**	0.20	0.17	0.22	0.11	**0.39**	0.14	0.26	**.46**	-0.03	**.48**	**-.43**	**0.33**	-0.17
Age	**.48**	**0.40**	-0.05	0.01	0.11	-0.16	-0.06	-0.24	0.19	-0.11	-0.14	-0.07	**-.51**	0.21	-0.06	0.22
Freq.	0.15	**.48**	0.00	**0.31**	0.13	**0.35**	**.72**	0.18	-0.23	**.46**	**.52**	0.20	**0.34**	-0.22	-0.07	**-0.39**
Dur.	0.01	**0.35**	-0.10	0.08	-0.16	0.13	**.63**	-0.14	-0.28	0.26	0.27	0.27	0.20	-0.16	**-0.38**	**-.42**
VO_{2peak}	-0.05	**0.39**	-0.23	-0.05	-0.23	-0.26	**.42**	**-.47**	**-0.35**	0.03	0.15	0.18	0.06	0.18	-0.12	-0.09

Note. Significant ($p < .05$) relationships are bolded. Exercise Frequency (Freq), Exercise Duration (Dur), Exercise-intensity Preference (Pref) and Tolerance (Tol), Relative Autonomy Index (RAI), Extraversion (E), Neurotisicm (N), Agreeableness (A), Conscientiousness (C), and Openness (O) traits. Vagal tone was recorded as baseline High-frequency Power (log).

Table 4.20

Relationships between Individual Differences and Pre-Exercise States

	HIIE						MIIE					
	Valence	Energy	Tired	Tense	Calm	Vagal Tone	Valence	Energy	Tired	Tense	Calm	Vagal Tone
BMI	**-0.43**	-0.16	**0.41**	-0.19	0.07	-0.26	-0.09	-0.03	0.20	-0.13	0.11	-0.25
Sex	**0.41**	-0.02	-0.21	0.04	-0.15	0.20	**0.37**	-0.15	-0.13	**-0.32**	-0.19	**0.35**
Age	**-0.40**	-0.28	0.20	-0.16	-0.15	**-0.32**	-0.04	0.00	0.29	0.22	0.06	**-0.43**
Exercise Frequency	0.19	-0.05	0.04	0.14	0.09	**0.39**	0.22	0.28	-0.27	0.02	-0.09	**0.45**
Exercise Duration	0.07	-0.14	-0.08	-0.24	**0.30**	**0.32**	-0.04	-0.15	**-0.54**	-0.20	-0.01	**0.33**
Exercise Length	-0.10	-0.20	**0.35**	-0.02	-0.08	0.07	**0.34**	0.13	0.18	0.04	0.00	0.09
Preference	**-0.50**	-0.26	**0.54**	-0.25	0.24	-0.18	-0.13	**0.31**	0.06	0.28	0.22	-0.29
Tolerance	0.06	-0.10	-0.15	-0.07	-0.03	0.19	0.12	0.24	0.16	**0.33**	0.14	0.17
BIS	-0.06	**-0.37**	0.29	0.07	-0.11	0.29	0.27	0.01	0.12	0.17	0.10	0.17
BAS-drive	0.23	0.12	0.10	-0.07	-0.05	**0.33**	0.12	-0.10	-0.21	-0.20	-0.26	**0.51**
BAS-fun seek	0.05	0.04	**0.35**	0.05	0.04	**-0.44**	-0.12	-0.22	0.08	-0.19	**-0.35**	-0.23
BAS-reward	0.13	-0.14	0.33	-0.16	0.12	**0.38**	0.24	0.06	-0.25	-0.11	-0.04	**0.41**
RAI	0.27	-0.05	-0.20	0.00	0.13	**0.56**	0.16	0.16	-0.21	0.09	0.10	**0.50**
Extraversion	0.24	**0.41**	-0.17	0.12	**-0.34**	-0.12	0.18	0.19	-0.15	-0.24	**-0.43**	-0.13
Neuroticism	-0.29	**-0.40**	0.28	-0.01	-0.05	-0.13	0.04	-0.08	**0.36**	0.17	0.10	-0.29
Agreeableness	0.15	-0.07	-0.19	0.23	-0.16	-0.04	0.27	-0.03	0.08	-0.17	-0.01	0.16
Conscientious	**0.63**	0.31	-0.35	0.05	0.00	**0.59**	**0.62**	0.16	**-0.42**	-0.19	-0.19	**0.61**
Openness	0.16	0.19	-0.17	-0.09	0.10	0.26	0.14	-0.01	-0.16	-0.07	-0.01	0.29
Tonic Vagal Tone	**0.61**	0.30	-0.37	0.00	-0.11	**0.68**	0.28	0.18	-0.19	-0.03	-0.05	**0.80**
Depression	**-0.44**	**-0.39**	0.16	-0.04	**0.37**	**-0.42**	-0.28	-0.27	**0.31**	0.29	**0.35**	**-0.44**
Anxiety	0.08	-0.24	-0.02	0.20	-0.11	0.05	0.21	-0.11	**0.31**	0.20	0.03	0.08
Stress	**-0.38**	**-0.36**	**0.35**	-0.02	0.15	-0.25	-0.18	-0.28	**0.42**	0.28	0.27	**-0.39**

Note. Significant ($p < .05$) relationships are bolded.

Individual Differences Predicting Affective Reactivity to HIIE

Differences in cardiorespiratory fitness (via VO_{2peak}), Neuroticism, Extraversion, Conscientiousness, Anxiety, Depression, and pre-exercise vagal tone (via HF-power), pre-valence, and pre-Energy were related to affective reactivity during the high-intensity interval exercise (HIIE) condition. A hierarchical regression revealed little-to-no explained variance in HIIE-valence by VO_{2peak} during the end of interval-1 ($R^2\Delta$ = .001, $F(1, 19)$= 1.013, p= .327), interval-2 ($R^2\Delta$ = .040, $F(1, 19)$= 1.828, p= .192), interval-3 ($R^2\Delta$ = .039, $F(1, 19)$=.762, p= .393), interval-4 ($R^2\Delta$ = .000, $F(1, 18)$=.005, p= .945), or interval-5 ($R^2\Delta$ = .014, $F(1, 16)$= .226, p= .641). Meaningful individual difference traits (i.e., Neuroticism, Extraversion, Conscientiousness, Anxiety, Depression) did explain unique variance during the end of interval-1 ($R^2\Delta$= .485, $F(6, 13)$= 2.269, p= .102), interval-2 ($R^2\Delta$= .331, $F(6, 13)$= 1.233, p= .351), interval-3 ($R^2\Delta$= .659, $F(6, 13)$= 7.432, p= .009), interval-4 ($R^2\Delta$= .650, $F(6, 12)$= 3.719, p= .025), and interval-5 ($R^2\Delta$= .285, $F(6, 13)$= 2.269, p= .102), potentially mediating the pre-exercise state variables during the end of interval-1 ($R^2\Delta$ = .058, $F(2, 11)$= .785, p= .480), interval-2 ($R^2\Delta$ = .049, $F(2, 11)$= .503, p= .618), interval-3 ($R^2\Delta$ = .016, $F(2, 11)$= .306, p= .742), interval-4 ($R^2\Delta$ = .082, $F(2, 10)$= 1.521, p= .265), and interval-5 ($R^2\Delta$ = .103, $F(2, 8)$= 1.077, p= .385). Together, cardiorespiratory fitness (via VO_{2peak}), Neuroticism, Extraversion, Conscientiousness, Anxiety, Depression, and pre-exercise vagal tone (via HF-power), pre-valence, and pre-Energy accounted for moderately large variance (interval-1= 59.4%, interval-2= 46.7%, interval-3= 71.4%, interval-4= 73.2%, interval-5= 61.6%) in affective reactivity during the end of the HIIE intervals.

Discussion

As it has been shown that trait variables influence reactivity to stimuli, the purpose of this study was to propose and examine a high-intensity exercise-affect reactivity model that considers biological dispositions, trait differences, and pre-exercise affective states as predictors and potential mediators of affective reactivity. The findings suggest several trait (self-report) and biological dispositions are related to one another. In an initial attempt to test the hypothesized model, selected variables significantly predicted exercise valence during the end of each HIIE interval. However, because the sample used to test the model was fairly small, the statistical model was underpowered. Thus, while promising, the results of this study should be interpreted with caution.

CHAPTER 5: GENERAL CONCLUSIONS

In order for cross-study exercise-intensity comparisons to be made, more than one relative intensity measure should be recorded in order to assure state-dependent changes are interpreted appropriately relative to the exercise-stress-load. Most importantly, the current findings suggest that rating of perceived exertion should be coupled with a physiological measure of intensity (e.g., HR, VO_2, blood lactate), especially for regular exercisers. Because the intensities performed during this study were more taxing than anticipated, any responses (affective, cardiac vagal tone) that occurred were interpreted from the perspective of the relative intensity performed (i.e., moderate-to-vigorous, vigorous-to-maximal intensity), rather than the intensity proposed (i.e., moderate- and high-intensity). Consistent with the extensive previous literature, high-intensity interval exercise (HIIE) resulted in more negative affective valence (i.e., decreased pleasantness, increased unpleasantness), along with greater activation and perceived stress during the intervals when compared to moderate-intensity interval exercise (MIIE). In spite of these affective differences during the two intensity conditions, reported enjoyment and satisfaction were similar for both. In addition, these findings suggest promise for high-intensity interval exercise prescription, as the degree of negative affective reactivity that occurred during both conditions was coupled with some affective rebound during the recovery periods. For example, while feelings states (i.e., affective valence) declined during each high-intensity exercise-interval, these declines were accompanied by a moderate rebound (towards more positive feeling states) during the recovery period between each consecutive interval. Thus, the "HIIE", reflective of vigorous-to-maximal intensity, did result in large affective declines from baseline, but the average affective valence never moved into an "unpleasant" state. This suggests the 1-min rest intervals provided some time for affective rebound which seems to have slowed (or stalled) the overall affective decline. On the other hand, MIIE, reaching a vigorous intensity as early as the second interval, resulted in improvements in feeling states during (at the beginning) the exercise intervals, with “negative reactivity” never declining below pre-exercise states.

These findings further suggest that those individuals with greater reported Depression and Stress had less vagal tone (i.e., reduced parasympathetic dominance) than their less-symptomatic counterparts. As the present findings suggest state-dependent associations between tonic vagal tone and affective states, where greater vagal tone was associated with more positive feeling states, this biological disposition is important to consider prior to prescribing exercise. It might perhaps suggest lower-intensity exercise for those suffering from Depression or high levels of stress. In addition, these findings suggest greater Neuroticism was related to more Anxiety and Stress symptoms, but not Depression. Affective (i.e., valence) reactivity and recovery were associated with numerous individual difference variables, particularly Neuroticism, Depression, Anxiety, and Stress, which were associated with more negative feeling states during the high-intensity interval exercise condition.

Lastly, in initial testing of the hypothesized high-intensity exercise-affect reactivity model, the findings suggest several trait (self-report) and biological dispositions are related to one another. Cardiovascular fitness, Extraversion, Neuroticism, Conscientiousness, dispositional vagal tone, and Anxiety, Depression, and Stress variables were significantly predictive of affective valence during the end of each high-intensity exercise interval, in-fact mediating any pre-exercise valence. However, as noted, the test of the model was statistically underpowered because of the relatively small sample. As such, these findings should be interpreted with a good deal of caution.

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APPENDIX A: HEALTH SCREENING FORM

ID#__________

Health Screening Form

CONFIDENTIAL MEDICAL HISTORY

Do you have a history of any of the following (if yes, please explain in the space provided below)?

1. **NERVOUS SYSTEM/PSYCHIATRY**
Frequent headaches, migraine, giddiness, fainting spells, epilepsy (fits), multiple sclerosis, nervous breakdown, anxiety disorder, depression, phobias, substance dependency, eating disorder, treated by psychiatrist or seen a counsellor before.
2. **EYE, EAR, NOSE, THROAT**
History of seeing black spots, bright lights, blur vision, hearing problems, ear infection, hearing loud noises (tinnitus), constant running nose, sneezing, blocked nose, nose bleeding.
3. **RESPIRATORY SYSTEM**
Asthma, frequent cough, tuberculosis, shortness of breath on and off.
4. **CARDIOVASCULAR SYSTEM**
Chest pain, palpitations, high blood pressure, heart murmur.
7. **ENDOCRINE SYSTEM**
Thyroid problem, diabetes
8. **MUSCULO-SKELETAL SYSTEM**
Frequent backache, knee pain on and off, frequent ankle sprains, neck problem, shoulder problem, gout, previous fracture.

Additional space for health history explanation (if needed):

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Data Protection Information

The Exercise Psychophysiology Laboratory holds your health records in confidence. Your responses to the above questions will be terminated following completion of the study sessions.